JC10 Rec'd PCT/PTO 29 OCT 2001

FORM PTO-1390 (Modified) (REV 11-2000) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER
112740-347

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR
10/018436

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/EP00/01263	**16 February 2000**	**29 April 1999**

TITLE OF INVENTION
METHOD FOR SYNCHRONIZING A BASE STATION WITH A MOBILE STATION, A BASE STATION AND A MOBILE STATION

APPLICANT(S) FOR DO/EO/US
Juergen Michel et al.

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include itens (5), (6), (9) and (24) indicated below.
4. ☒ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
   a. ☒ is attached hereto (required only if not communicated by the International Bureau).
   b. ☐ has been communicated by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
   a. ☒ is attached hereto.
   b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
   a. ☒ are attached hereto (required only if not communicated by the International Bureau).
   b. ☐ have been communicated by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☐ have not been made and will not be made.
8. ☒ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
10. ☐ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).
11. ☒ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☒ A copy of the International Search Report (PCT/ISA/210).

Items 13 to 20 below concern document(s) or information included:

13. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☒ A **FIRST** preliminary amendment.
16. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
17. ☒ A substitute specification.
18. ☐ A change of power of attorney and/or address letter.
19. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
20. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
21. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
22. ☒ Certificate of Mailing by Express Mail
23. ☐ Other items or information:

PCTUS1/REV03

531 Rec'd PCT/PTO 29 OCT 2001

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR 10/018436	INTERNATIONAL APPLICATION NO. PCT/EP00/01263	ATTORNEY'S DOCKET NUMBER 112740-347

24. The following fees are submitted:.

	CALCULATIONS	PTO USE ONLY
BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :		
☐ Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO **$1040.00**		
☒ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO **$890.00**		
☐ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO **$740.00**		
☐ International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) **$710.00**		
☐ International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) **$100.00**		
ENTER APPROPRIATE BASIC FEE AMOUNT =	**$890.00**	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).	**$0.00**	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	17 - 20 =	0	x $18.00	**$0.00**	
Independent claims	5 - 3 =	2	x $84.00	**$168.00**	
Multiple Dependent Claims **(check if applicable)**.			☐	**$0.00**	

TOTAL OF ABOVE CALCULATIONS =	**$1,058.00**	
☐ Applicant claims small entity status. See 37 CFR 1.27). The fees indicated above are reduced by 1/2.	**$0.00**	
SUBTOTAL =	**$1,058.00**	
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (f)). +	**$0.00**	
TOTAL NATIONAL FEE =	**$1,058.00**	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) **(check if applicable)**. ☐	**$0.00**	
TOTAL FEES ENCLOSED =	**$1,058.00**	
	Amount to be: refunded	$
	charged	$

a. ☒ A check in the amount of **$1,058.00** to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. ____________ in the amount of ____________ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. **02-1818** A duplicate copy of this sheet is enclosed.

d. ☐ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit card information should not be included on this form.** Provide credit card information and authorization on PTO-2038.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

William E. Vaughan (Reg. No. 39,056)
Bell, Boyd & Lloyd LLC
P.O. Box 1135
Chicago, Illinois 60690-1135
(312) 807-4292

SIGNATURE

William E. Vaughan
NAME

39,056
REGISTRATION NUMBER

October 29, 2001
DATE

BOX PCT

IN THE UNITED STATES ELECTED/DESIGNATED OFFICE
OF THE UNITED STATES PATENT AND TRADEMARK OFFICE
UNDER THE PATENT COOPERATION TREATY-CHAPTER II

PRELIMINARY AMENDMENT

APPLICANTS:	Juergen Michel et al.	DOCKET NO: 112740-347
SERIAL NO:		GROUP ART UNIT:
		EXAMINER:

INTERNATIONAL APPLICATION NO: PCT/EP00/01263

INTERNATIONAL FILING DATE: 16 February 2000

INVENTION: METHOD FOR SYNCHRONIZING A BASE STATION WITH A MOBILE STATION, A BASE STATION AND A MOBILE STATION

Assistant Commissioner for Patents,
Washington, D.C. 20231

Sir:

Please amend the above-identified International Application before entry into the National stage before the U.S. Patent and Trademark Office under 35 U.S.C. §371 as follows:

In the Specification:

Please replace the Specification of the present application, including the Abstract, with the following Substitute Specification:

SPECIFICATION

TITLE OF THE INVENTION

METHOD FOR SYNCHRONIZING A BASE STATION WITH A MOBILE STATION, A BASE STATION AND A MOBILE STATION

BACKGROUND OF THE INVENTION

In signal transmission systems, such as mobile radio systems, it is necessary for one of the communication partners (first transmission unit) to detect specific fixed signals which are emitted by another communication partner (second transmission unit). These can be, for example, what are termed synchronization

bursts for synchronizing two synchronization partners such as radio stations, for example, or what are termed access bursts.

In order to detect or identify such received signals reliably by contrast with the ambient noise, it is known to correlate the received signal continuously with a prescribed synchronization sequence over a fixed time duration, and to form the correlation sum over the time duration of the prescribed synchronization sequence. The range of the received signal, which yields a maximum correlation sum, corresponds to the signal being searched for. Connected upstream, as what is termed a training sequence, of the synchronization signal from the base station of a digital mobile radio system is, for example, a synchronization sequence which is detected or determined in the mobile station in the way just described by correlation with the stored synchronization sequence.

Such correlation calculations are also necessary in the base station; for example, in the case of random-access-channel (RACH) detection. Moreover, a correlation calculation is also carried out to determine the channel pulse response and the signal propagation times of received signal bursts.

The correlation sum is calculated as follows in this case:

$$Sm = \sum_{i=0}^{n-1} E(i+m) * K(i)$$

E(i) being a received signal sequence derived from the received signal, and K(i) being the prescribed synchronization sequence, i running from 0 to n-1. The correlation sum Sm is calculated sequentially for a number of temporally offset signal sequences E(i) obtained from the received signal, and then the maximum value of Sm is determined. If k sequential correlation sums are to be calculated, the outlay on calculation is k * n operations, a multiplication and addition being counted together as one operation.

The calculation of the correlation sums is, therefore, very complicated and, particularly in real time applications such as voice communication or video-telephony or in CDMA systems, requires powerful and expensive processors which

have a high power consumption during calculation. For example, a known synchronization sequence of length 256 chips (a transmitted bit is also termed a chip in CDMA) is to be determined for the purpose of synchronizing the UMTS mobile radio system, which is being standardized. The sequence is repeated every 2560 chips. Since the mobile station initially operates asynchronously relative to the chip clock, the received signal must be oversampled in order still to retain an adequate signal even given an unfavorable sampling situation. Because of the sampling of the I and Q components, this leads to 256*2560*2*2 = 2621440 operations.

WO 96 39749 A discloses transmitting a synchronization sequence, a chip of the sequence itself being a sequence.

"Srdjan Budisin: Golay Complementary Sequences are Superior to PN Sequences, Proceedings of the International Conference on Systems Engineering, US, New York, IEEE, Vol.-, 1992, pages 101-104, XP 000319401 ISBN: 0-7803-0734-8" discloses using Golay sequences as an alternative to PN sequences.

It is an object of the present invention to specify methods for synchronizing a base station with a mobile station, as well as to specify both a base station and a mobile station, which permits synchronization of a base station with a mobile station and which is reliable and favorable in terms of outlay.

SUMMARY OF THE INVENTION

In this case, firstly, the present invention is based on the idea of forming what is termed a "hierarchical sequence"; in particular, a hierarchical synchronization sequence y(i) which is based in accordance with the following relationship on a first constituent sequence x1 of length n1 and a second constituent sequence x2 of length n2:

$$y(i) = x_2(i \bmod n_2) * x_1(i \operatorname{div} n_2) \text{ for } i = 0 \ldots (n_1 * n_2) - 1$$

This design principle of a hierarchical synchronization sequence envisages a repetition of a constituent sequences in their full length, the repetitions being modulated with the value of the corresponding element of the second constituent sequence. It is, thereby, possible to form synchronization sequences which can be

determined easily when they are contained in a received signal sequence. Such synchronization sequences have good correlation properties and permit efficient calculation of the correlation in a mobile station. It was possible to show this via complex simulation tools created specifically for this purpose.

Furthermore, the present invention is based on the finding that, in the case of the use of a hierarchical sequence as synchronization sequence which is based on two constituent sequences, it is possible to achieve a further reduction in complexity at the receiving end when at least one constituent sequence itself is a hierarchical sequence.

It is provided in this case that only one repetition of the first half (or another part) of the first constituent sequence is carried out, followed thereupon by the second half and its repetitions. The repetitions are modulated once again with the value of the corresponding element of the second constituent sequence. A parameter s is introduced which specifies the part of the constituent sequence which is repeated as a coherent piece. The formula describing this generalized developed formulation for forming "generalized hierarchical sequences" runs:

$$x_1(i) = x_4(i \bmod s + s \cdot (i \operatorname{div} sn_3)) \cdot x_3((i \operatorname{div} s) \bmod n_3), \text{ for } i = 0 \ldots n_3 \cdot n_4 - 1$$

For $s=n_4$, this relationship for describing "generalized hierarchical sequences" is equivalent to the relationship explained above for forming "hierarchical synchronization sequences".

Within the scope of the present invention, "constituent sequences" as well as "partial signal sequences" are denoted as K1 and K2, respectively, or as x1 and x_1, respectively, or as x2 and x_2, respectively. "Synchronization sequences" or "synchronization codes" are also denoted as "y(i)" or "K(i)". Of course, "determination of a synchronization sequence" is also understood as the determination of the temporal position of a synchronization sequence. The term "received signal sequence" is also understood as a signal sequence which is derived from a received signal by demodulation, filtering, derotation, scaling or analog-to-digital conversion, for example.

A development of the present invention is based on the finding that, in the case of the use of a hierarchical sequence as synchronization sequence which is based on two constituent sequences, at least one constituent sequence being a Golay sequence, it is possible to achieve a further reduction in complexity at the receiving end.

It was possible through the use of complicated simulations to find parameters for describing Golay sequences which are particularly well suited as constituent sequences.

Specific refinements of the present invention provide for using constituent sequences of length 16 to form a hierarchical 256 chip sequence; in particular, a synchronization sequence, a first constituent sequence being a Golay sequence, and a second constituent sequence being a generalized hierarchical sequence whose constituent sequences are based on two Golay sequences (of length 4). For example, x_2 is defined as the Golay sequence of length 16 which is obtained by the delay matrix $D^2 = [8, 4, 1,2]$ and the weight matrix $W^2 = [1, -1, 1,1]$. x_1 is a generalized hierarchical sequence, in which case s=2 and the two Golay sequences x_3 and x_4 are used as constituent sequences. x_3 and x_4 are identical and are defined as Golay sequences of length 4 which are described by the delay matrix $D^3 = D^4 = [1, 2]$ and the weight matrix $W^3 = W^4 = [1, 1]$.

A Golay sequence a_N, also denoted as a Golay complementary sequence, can be formed in this case using the following relationship:

$$a_0(k) = \delta(k) \text{ and } b_0(k) = \delta(k)$$

$$a_n(k) = a_{n-1}(k) + W_n \cdot b_{n-1}(k-D_n),$$

$$b_n(k) = a_{n-1}(k) - W_n \cdot b_{n-1}(k-D_n),$$

$$k = 0, 1, 2, \ldots, 2^N,$$

$$n = 1, 2, \ldots, N.$$

$\delta(k)$ Kronecker delta function

D Delay matrix

W Weight matrix

Additional features and advantages of the present invention are described in, and will be apparent from, the following Detailed Description of the Invention and the Figures.

BRIEF DESCRIPTION OF THE FIGURES

Figure 1 shows a schematic of a mobile radio network.

Figure 2 shows a block diagram of a radio station.

Figure 3 shows a conventional method for calculating correlation sums.

Figures 4, 5, 6, 7 and 8 show block diagrams of efficient Golay correlators in connection with the teachings of the present invention.

Figure 9 shows a diagram with simulation results.

DETAILED DESCRIPTION OF THE INVENTION

Illustrated in Figure 1 is a cellular mobile radio network such as, for example, the GSM (Global System for Mobile Communication), which includes a multiplicity of mobile switching centers MSC which are networked with one another and/or provide access to a fixed network PSTN/ISDN. Furthermore, these mobile switching centers MSC are connected to, in each case, at least one base station controller BSC, which can also be formed by a data processing system. A similar architecture is also to be found in a UMTS (Universal Mobile Telecommunication System).

Each base station controller BSC is connected, in turn, to at least one base station BS. Such a base station BS is a radio station which can use an air interface to set up a radio link to other radio stations, what are termed mobile stations MS. Information inside radio channels f which are situated inside frequency bands b can be transmitted via radio signals between the mobile stations MS and the base station BS assigned to these mobile stations MS. The range of the radio signals of a base station substantially defines a radio cell FZ.

Base stations BS and a base station controller BSC can be combined to form a base station system BSS. The base station system BSS is also responsible in this case for radio channel management and/or assignment, data rate matching, monitoring the radio transmission link, hand-over procedures and, in the case of a

CDMA system, assigning the spread code set to be used, and transfers the signaling information required for this purpose to the mobile stations MS.

For FDD (Frequency-Division Duplex) systems such as the GSM, it is possible in the case of a duplex system to provide for the uplink u (mobile station (transmitting unit) to the base station (receiving unit)) frequency bands differing from those for the downlink d (base station (transmitting unit) to the mobile station (receiving unit)). A number of frequency channels f can be implemented within the different frequency bands b via an FDMA (Frequency-Division Multiple Access) method.

Within the scope of the present application, the transmission unit is also understood as a communication unit, transmitting unit, receiving unit, communication terminal, radio station, mobile station or base station. Terms and examples used within the scope of this application frequently refer also to a GSM mobile radio system; however, they are not in any way limited thereto, but easily can be mapped by a person skilled in the art with the aid of the description onto other, possibly future, mobile radio systems. Such systems would include, for example, CDMA systems; in particular, wide-band CDMA systems.

Data can be efficiently transmitted, separated and assigned to one or more specific links and/or to the appropriate subscriber via an air interface via multiple access methods. It is possible to make use for this purpose of time-division multiple access TDMA, frequency-division multiple access FDMA, code-division multiple access CDMA or a combination of a number of these multiple access methods.

In FDMA, the frequency band b is broken down into a number of frequency channels f. These frequency channels are split up into time slots ts via time-division multiple access TDMA. The signals transmitted within a time slot ts and a frequency channel f can be separated via spread codes, what are termed CDMA codes cc, that are modulated in a link-specific fashion onto the data.

The physical channels thus produced are assigned to logic channels according to a fixed scheme. The logic channels are basically distinguished into

two types: signaling channels (or control channels) for transmitting signaling information (or control information), and traffic channels (TCH) for transmitting useful data.

The signaling channels are further subdivided into:

- broadcast channels
- common control channels
- dedicated/access control channels DCCH/ACCH

The group of broadcast channels includes the broadcast control channel BCCH, through which the MS receives radio information from the base station system BSS, the frequency correction channel FCCH and the synchronization channel SCH. The common control channels include the random access channel RACH. The bursts or signal sequences that are transmitted to implement these logic channels can include, in this case, for different purposes synchronization sequences K(i), what are termed correlation sequences, or synchronization sequences K(i) can be transmitted on these logic channels for different purposes.

A method for synchronizing a mobile station MS with a base station BS is explained now by way of example. During a first step of the initial search for a base station or search for a cell (initial cell search procedure), the mobile station uses the primary synchronization channel (SCH (PSC)) in order to achieve a time slot synchronization with the strongest base station. This can be ensured via a matched filter or an appropriate circuit which is matched to the primary synchronization code cp (synchronization sequence) that is emitted by all the base stations. In this case, all the base stations BS emit the same primary synchronization code cp of length 256.

The mobile station uses correlation to determine from a received sequence the received synchronization sequences K(i). In this case, peaks are output at the output of a matched filter for each received synchronization sequence of each base station located within the reception area of the mobile station. The detection of the position of the strongest peak permits the determination of the timing of the strongest base station modulo of the slot length. In order to ensure a greater

reliability, the output of the matched filter can be accumulated over the number of time slots in a non-coherent fashion. The mobile station therefore carries out a correlation over a synchronization sequence of length 256 chips as a matched-filter operation.

The synchronization code cp can be formed in this case according to a hierarchical synchronization sequence K(i) or y(i) using the following relationships from two constituent sequences x_1 and x_2 of length n_1 and n_2 respectively:

$$y(i) = x_2(i \bmod n_2) * x_1(i \operatorname{div} n_2) \text{ for } i = 0 \ldots (n_1 * n_2) - 1$$

The constituent sequences x_1 and x_2 are of length 16 (that is to say, $n_1 = n_2 = 16$), and are defined by the following relationships:

$$x_1(i) = x_4(i \bmod s + s*(i \operatorname{div} sn_3)) * x_3((i \operatorname{div} s) \bmod n_3),\ i = 0 \ldots (n_3 * n_4) - 1$$

$\mathbf{x_1}$ is, thus, a generalized hierarchical sequence using the above formula, in which case s=2 is selected and the two Golay sequences x_3 and x_4 are used as constituent sequences.

$\mathbf{x_2}$ is defined as the Golay sequence of length 16 (N_2=2) which is obtained via the delay matrix $D^2 = [8, 4, 1,2]$ and the weight matrix $W^2 = [1, -1, 1,1]$.

$\mathbf{x_3}$ and x_4 are identical Golay sequences of length 4 (N = 2), which are defined by the delay matrix $D^3 = D^4 = [1, 2]$ and the weight matrix $W^3 = W^4 = [1, 1]$.

The Golay sequences are defined using the following recursive relationship:

$$a_0(k) = \delta(k) \text{ and } b_0(k) = \delta(k)$$

$$a_n(k) = a_{n-1}(k) + W_n \cdot b_{n-1}(k-D_n),$$

$$b_n(k) = a_{n-1}(k) - W_n \cdot b_{n-1}(k-D_n),$$

$$k = 0, 1, 2, \ldots, 2^N,$$

$$n = 1, 2, \ldots, N.$$

$\boldsymbol{a_N}$ then defines the required Golay sequence.

Figure 2 shows a radio station which can be a mobile station MS, which includes an operating unit or interface unit MMI, a control device STE, a processing device VE, a power supply device SVE, a receiving device EE and, if appropriate, a transmitting device SE.

The control device STE essentially includes a program-controlled microcontroller MC which can access memory chips SPE by writing and reading. The microcontroller MC controls and monitors all essential elements and functions of the radio station.

The processing device VE also can be formed by a digital signal processor DSP, which can likewise access memory chips SPE. Addition and multiplication also can be achieved via the processing device VE.

The microcontroller MC and/or the digital signal processor DSP and/or storage devices SPE and/or further computing elements known as such to a person skilled in the art can be combined in this case to form a processor device which is set up in such a way that the method of the present invention can be carried out.

The program data required for controlling the radio station and the communication cycle, as well as, in particular, the signaling procedures, and information produced during the processing of signals are stored in the volatile or nonvolatile memory chips SPE. Moreover, synchronization sequences K(i) which are used for correlation purposes, and intermediate results of correlation sum calculations can be stored therein. The synchronization sequences K(i) within the scope of the present invention can, thus, be stored in the mobile station and/or the base station. It is also possible for one or more of parameters for defining synchronization sequences or partial signal sequences or partial signal sequence pairs (K1(j);K2(k)) derived therefrom to be stored in the mobile station and/or the base station. It is also possible for a synchronization sequence K(i) to be formed from a partial signal sequence pair (K1(j);K2(k)) and/or one or more parameters for defining synchronization sequences or partial signal sequences derived therefrom in the mobile station and/or the base station.

In particular, it is possible to store in a base station, or in all the base stations in a system, a synchronization sequence K(i) which is emitted at fixed or variable intervals for synchronization purposes. Constituent sequences (partial signal sequences) or parameters from which the synchronization sequence K(i) stored in the base station can be, or are, formed are stored in the mobile station MS

and are used to synchronize the mobile station with a base station in order to calculate the correlation sum favorably in terms of computational outlay.

The storage of the synchronization sequences or the partial signal sequences or parameters also can be performed by storing appropriate information in arbitrarily coded form, and can be implemented with the aid of storage devices such as, for example, volatile and/or nonvolatile memory chips or via appropriately designed adder or multiplier inputs or appropriate hardware configurations which have the same effect.

The high-frequency section HF includes, if appropriate, the transmitting device SE, with a modulator and an amplifier V, and a receiving device EE with a demodulator and, likewise, an amplifier. The analog audio signals and the analog signals originating from the receiving device EE are converted via analog-to-digital conversion into digital signals and processed by the digital signal processor DSP. After processing, the digital signals are converted, if appropriate, by digital-to-analog conversion into analog audio signals or other output signals and analog signals that are to be fed to the transmitting device SE. Modulation or demodulation, respectively, is carried out for this purpose, if appropriate.

The transmitting device SE and the receiving device EE are fed with the frequency of a voltage-controlled oscillator VCO via the synthesizer SYN. The system clock for timing processor devices of the radio station also can be generated via the voltage-controlled oscillator VCO.

An antenna device ANT is provided for receiving and for transmitting signals via the air interface of a mobile radio system. The signals are received and transmitted in what are termed bursts that are pulsed over time in the case of some known mobile radio systems such as the GSM (Global System for Mobile Communication).

The radio station also may be a base station BS. In this case, the loudspeaker element and the microphone element of the operating unit MMI are replaced by a link to a mobile radio network, for example via a base station controller BSC or a switching device MSC. The base station BS has an appropriate

multiplicity of transmitting and receiving devices, respectively, in order to exchange data simultaneously with a number of mobile stations MS.

A received signal sequence E(l), which also can be a signal sequence derived from a received signal, of length W is illustrated in Figure 3. In order to calculate a first correlation sum S0 in accordance with the formula specified at the beginning, elements of a first section of this received signal sequence E(l) are multiplied in pairs by the corresponding elements of the synchronization sequence K(i) of length n, and the length of the resulting partial results is added to the correlation sum S0.

In order to calculate a further correlation sum S1, as illustrated in the Figure 3, the synchronization sequence K(i) is shifted to the right by one element, and the elements of the synchronization sequence K(i) are multiplied in pairs by the corresponding elements of the signal sequence E(l), and the correlation sum S1 is formed again by summing the partial results produced.

The pairwise multiplication of the elements of the synchronization sequence by corresponding elements of the received signal sequence, and the subsequent summation also can be described in vector notation as the formation of a scalar product, if the elements of the synchronization sequence and the elements of the received synchronization sequence are respectively combined to form a vector:

$$S0 = \begin{pmatrix} K(0) \\ \vdots \\ K(i) \\ \vdots \\ K(n-1) \end{pmatrix} * \begin{pmatrix} E(0) \\ \vdots \\ E(i) \\ \vdots \\ E(n-1) \end{pmatrix} = K(0) * E(0) + \ldots + K(i) * E(i) + \ldots + K(n-1) * E(n-1)$$

$$S1 = \begin{pmatrix} K(0) \\ \vdots \\ K(i) \\ \vdots \\ K(n-1) \end{pmatrix} * \begin{pmatrix} E(1) \\ \vdots \\ E(i+1) \\ \vdots \\ E(n) \end{pmatrix} = K(0) * E(1) + \ldots + K(i) * E(i+1) + \ldots + K(n-1) * E(n)$$

In the correlation sums S thus determined, it is possible to search for the maximum and compare the maximum of the correlation sums S with a prescribed threshold value and, thus, determine whether the prescribed synchronization sequence K(i) is included in the received signal E(l) and, if so, where it is located in the received signal E(l) and thus two radio stations are synchronized with one another or data are detected on to which an individual spread code has been modulated in the form of a synchronization sequence K(i).

Figure 4 shows an efficient hierarchical correlator for synchronization sequences, Golay sequences X,Y of length nx and ny respectively being used as constituent sequences K1, K2. The correlator consists of two series-connected matched filters (Figure 4 a) which are respectively formed as efficient Golay correlators. Figure 4 b shows the matched filter for the sequence X, and Figure 4 c shows the matched filter for the sequence Y.

The following designations apply in Figure 4 b:

n = 1, 2, ...NX	
ny	length of sequence Y
nx	length of sequence X
NX	with $nx=2^{NH}$
DX_n	$DX_n = 2^{PX_n}$
PX_n	permutation of the numbers {0, 1, 2, ..., NX-1} for the partial signal sequence X
WX_n	weights for the partial signal sequence X from (+1,-1,+i or -i).

The following designations apply in Figure 4 c:

n = 1, 2, ...NY	
ny	length of sequence Y
NY	with $ny=2^{NY}$
DY_n	$DY_n = 2^{PY_n}$
PY_n	permutation of the numbers {0, 1, 2, ..., NY-1} for the partial signal sequence Y

WY_n	weights for the partial signal sequence Y from (+1,-1,+i or -i).

Moreover, the following definitions and designations are valid in this variant design:

$a_n(k)$ and $b_n(k)$ are two complex sequences of length 2^N,

$\delta(k)$ is the Kronecker delta function,

k is an integer representing time,

n is the iteration number,

D_n is the delay,

P_n , $n = 1, 2, \ldots, N$, is an arbitrary permutation of the numbers $\{0, 1, 2, \ldots, N\text{-}1\}$,

W_n can assume the values +1, -1, +i, -i as weights.

The correlation of a Golay sequence of length 2^N can be carried out efficiently as follows:

The sequences $R_a^{(0)}(k)$ and $R^{(0)}(k)$ are defined as $R_a^{(0)}(k) = R_b^{(0)}(k) = r(k)$, r(k) being the received signal or the output of another correlation stage.

The following step is executed N times, n running from 1 to N:

Calculate

$$R_a^{(n)}(k) = W^*_n * R_b^{(n-1)}(k) + R_a^{(n-1)}(k - D_n)$$

And

$$R_b^{(n)}(k) = W^*_n * R_b^{(n-1)}(k) + R_a^{(n-1)}(k - D_n)$$

In this case, W^*_n designates the complex conjugate of W_n. If the weights W are real, W^*_n is identical to W_n.

$R_a^{(n)}(k)$ is then the correlation sum to be calculated.

An efficient Golay correlator for a synchronization sequence of length 256 (2^8) chips in the receiver generally has 2*·8-1=15 complex adders.

With the combination of hierarchical correlation and efficient Golay correlator, a hierarchical code (described by two constituent sequences X and Y) of length 256 ($2^4 \cdot 2^4$) requires only $2 \cdot 4-1+2 \cdot 4-1 = 14$ complex adders (even in the case when use is made of four-valued constituent sequences).

This reduces by 7% the outlay on calculation, which is very high for the primary synchronization in CDMA mobile radio systems, because efficient hierarchical correlators and Golay correlators can be combined. A possible implementation of the overall correlator, an efficient truncated Golay correlator for generalized hierarchical Golay sequences, is shown in Figure 5. This is also designated as a truncated Golay correlator, because one of the outputs is truncated in specific stages, and instead of this another output is used as input for the next stage.

The vector D is defined by D = [128, 16, 64, 32, 8, 4, 1, 2] and W = [1, -1, 1, 1, 1, 1, 1, 1]. This correlator requires only 13 additions per calculated correlation sum.

By comparison with a sequence having a simple hierarchical or Golay-supported structure, the generalized hierarchical Golay sequence offers advantages based on more efficient options for calculating the correlation sum with the aid of this Golay sequence. However, simulations exhibit good results with regard to slot synchronization even in the case of relatively high frequency errors.

The hierarchical Golay sequences are compared below with the two simple methods.

Figure 6 shows firstly an efficient correlator for simple hierarchical sequences, and a simple correlation method for the hierarchical correlation.

The hierarchical correlation consists of two concatenated, matched filter blocks which, in each case, carry out a standardized correlation via one of the constituent sequences. It is assumed that the correlation via X_1 (16-symbol accumulation) is carried out before the correlation via X_2 (16-chip accumulation). This is one implementation option, because the two matched filter blocks (enclosed in dashed lines in Figure 6) are linear systems which can be connected in any

desired sequence. 240·n delay lines with the minimum word length can be implemented in this way since no accumulation is performed in advance and, therefore, no signal/interference gain is achieved. Here, n designates the oversampling factor, that is to say how many samples are carried out per chip interval.

As already mentioned, one or both of the matched filter blocks again can be replaced by a correlator for a (generalized) hierarchical sequence or by an efficient Golay correlator (EGC).

Figure 7 shows a simple correlation method for the efficient Golay correlator (EGC) for a simple Golay sequence. The design of an efficient hierarchical Golay correlator corresponds to an efficient correlator for simple hierarchical sequences (see Figure 6), with the exception that two adders can be omitted.

Figure 8 now shows an efficient Golay correlator for a generalized hierarchical Golay sequence. The saving of two adders from 15 adders clearly reduces the complexity of the method accordingly.

Figure 9 shows simulation results, the slot-synchronization step having been investigated in a single-path Rayleigh fading channel with 3 km/h for various chip/noise ratios (CNR) without and with frequency errors. It is shown that, by comparison with another synchronization code, designated as S_{new} below, the above-defined synchronization code, designated as GHG below, is just as well suited in practice with regard to the slot-synchronization power. Results are available for the use of averaging with 24 slots. A secondary synchronization channel, which is based on a random selection from 32 symbols, is transmitted in common with the primary synchronization channel (PSC). The graph shows that there is no substantial difference between the synchronization code S_{new} and the generalized hierarchical Golay synchronization code GHG for no frequency error and for a frequency error of 10 kHz.

The proposed synchronization sequence GHG has better autocorrelation properties than S_{old} (dotted curve), particularly in the case of 10 kHz. The graph

shows that the synchronization properties of GHG are thus optimal with reference to the practical use. S_{old} is a hierarchical correlation sequence that is not especially optimized for frequency errors.

The use of the generalized hierarchical Golay sequences for the primary synchronization channel (PSC) thus reduces the computational complexity at the receiving end; the complexity is reduced to only 13 additions by comparison with the conventional sequences of 30 additions and/or by comparison with Golay sequences of 15 additions per output sample.

The simulations show that the proposed synchronization sequence GHG have good synchronization properties in the case both of low and of relatively high errors. Because of a lower computational complexity, less specific hardware is required for implementation, and a lower power consumption is achieved.

Although the present invention has been described with reference to specific embodiments, those of skill in the art will recognize that changes may be made thereto without departing from the spirit and scope of the invention as set forth in the hereafter appended claims.

ABSTRACT OF THE DISCLOSURE

Method for forming and/or determining a synchronization sequence, a synchronization method, a transmitting unit and a receiving unit, the formation of synchronization sequences, which are based on partial signal sequences, includes a second partial signal sequence being repeated and modulated in the process by a first partial signal sequence.

In the claims:

On page 22, cancel line 1, and substitute the following left hand justified heading therefore:

CLAIMS

Please cancel claims 1-16, without prejudice, and substitute the following claims therefore:

17. A method for synchronizing a base station with a mobile station, the method comprising the steps of:

forming a synchronization sequence y(i) of length n, to be emitted by the base station, in accordance with the following relationship from a first constituent sequence x1 of length n1 and a second constituent sequence x2 of length n2: $y(i) = x_2(i \bmod n_2) * x_1(i \operatorname{div} n_2)$ for $i = 0 \ldots (n_1 * n_2) - 1$; and

forming at least one constituent sequence x_1 or x_2 in accordance with the following relationship from a third constituent sequence x3 of length n3 and a fourth constituent sequence x4 of length n4:

$x_1(i) = x_4(i \bmod s + s*(i \operatorname{div} sn_3)) * x_3((i \operatorname{div} s) \bmod n_3),\ i = 0 \ldots (n_3 * n_4) - 1$; or

$x_2(i) = x_4(i \bmod s + s*(i \operatorname{div} sn_3)) * x_3((i \operatorname{div} s) \bmod n_3),\ i = 0 \ldots (n_3 * n_4) - 1$.

18. A method for synchronizing a base station with a mobile station as claimed in claim 17, wherein the synchronization sequence y(i) is of length 256, and the constituent sequences x1, x2 are of length 16.

19. A method for synchronizing a base station with a mobile station as claimed in claim 17, wherein at least one of the constituent sequences x1 or x2 is a Golay sequence.

20. A method for synchronizing a base station with a mobile station as claimed in claim 19, wherein at least one of the two constituent sequences x_1 or x_2 is a Golay sequence which is based on the following parameters:

delay matrix $D^1 = [8, 4, 1,2]$ and weight matrix $W^1 = [1, -1, 1,1]$; or
delay matrix $D^2 = [8, 4, 1,2]$ and weight matrix $W^2 = [1, -1, 1,1]$.

21. A method for synchronizing a base station with a mobile station as claimed in claim 17, wherein x_3 and x_4 are identical Golay sequences of length 4 and are based on the following parameters:

delay matrix $D^3 = D^4 = [1, 2]$ and weight matrix $W^3 = W^4 = [1,1]$.

22. A method for synchronizing a base station with a mobile station as claimed in claim 19, wherein a Golay sequence a_N is defined by the following recursive relationship:

$$a_0(k) = \delta(k) \text{ and } b_0(k) = \delta(k)$$

$$a_n(k) = a_{n-1}(k) + W_n \cdot b_{n-1}(k-D_n),$$

$$b_n(k) = a_{n-1}(k) - W_n \cdot b_{n-1}(k-D_n),$$

$$k = 0, 1, 2, \ldots, 2^N,$$

$$n = 1, 2, \ldots, N,$$

$\delta(k)$ *Kronecker delta function*

23. A method for synchronizing a base station with a mobile station as claimed in claim 17, wherein the synchronization sequence y(i) is received by a mobile station and processed for synchronization purposes.

24. A method for synchronizing a base station with a mobile station as claimed in claim 17, wherein in order to determine a prescribed synchronization sequence y(i) contained in a received signal sequence, correlation sums of the synchronization sequence y(i) are determined in the mobile station with the aid of corresponding sections of the received signal sequence.

25. A method for synchronizing a base station with a mobile station as claimed in claim 24, at least one efficient Golay correlator is used to determine at least one correlation sum.

26. A transmitting unit comprising:

a part for storing or forming a synchronization sequence y(i), which can be formed in accordance with the following relationship from a first constituent sequence x1 of length n1 and a second constituent sequence x2 of length n2:

$y(i) = x_2(i \bmod n_2) * x_1(i \operatorname{div} n_2)$ for $i = 0 \ldots (n_1 * n_2) - 1$, wherein it is further possible to form at least one constituent sequence x_1 or x_2 in accordance with the following relationship from a third constituent sequence x3 of length n3 and a fourth constituent sequence x4 of length n4:

$x_1(i) = x_4(i \bmod s + s*(i \operatorname{div} sn_3)) * x_3((i \operatorname{div} s) \bmod n_3),\ i = 0 \ldots (n_3 * n_4) - 1$; or

$x_2(i) = x_4(i \bmod s + s*(i \operatorname{div} sn_3)) * x_3((i \operatorname{div} s) \bmod n_3),\ i = 0 \ldots (n_3 * n_4) - 1$, and

a part for emitting the synchronization sequence y(i) for synchronization with a receiving unit.

27. A mobile station comprising:

a part for receiving a received signal sequence; and

a part for determining a synchronization sequence y(i), which can be formed in accordance with the following relationship from a first constituent sequence x1 of length n1 and a second constituent sequence x2 of length n2:

$y(i) = x_2(i \bmod n_2) * x_1(i \operatorname{div} n_2)$ for $i = 0 \ldots (n_1 * n_2) - 1$, wherein it is further possible to form at least one constituent sequence x_1 or x_2 in accordance with the following relationship from a third constituent sequence x3 of length n3 and a fourth constituent sequence x4 of length n4:

$x_1(i) = x_4(i \bmod s + s*(i \operatorname{div} sn_3)) * x_3((i \operatorname{div} s) \bmod n_3),\ i = 0 \ldots (n_3 * n_4) - 1$; *or*

$x_2(i) = x_4(i \bmod s + s*(i \operatorname{div} sn_3)) * x_3((i \operatorname{div} s) \bmod n_3),\ i = 0 \ldots (n_3 * n_4) - 1$.

28. A mobile station as claimed in claim 27, wherein the part for determining the synchronization sequence y(i) includes at least one efficient Golay correlator.

29. The mobile station as claimed in claim 27, wherein the part for determining the synchronization sequence y(i) includes two series-connected matched filters which are designed as efficient Golay correlators.

30. A method for transmitting and receiving synchronization sequences, the method comprising the steps of:

composing a synchronization sequence from two constituent sequences;

repeating a first constituent sequence in accordance with the number of elements of a second constituent sequence;

modulating all the elements of a specific repetition of the first constituent sequence with the corresponding element of the second constituent sequences; and

mutually interleaving the repetitions of the first constituent sequence.

31. A method for transmitting and receiving synchronization sequences, the method comprising the steps of composing a synchronization sequence $y(i)$ *of length* $(n_1 * n_2)$ from two constituent sequences x_1 and x_2 *of length* n_1 and n_2 in accordance with the formula $y(i) = x_2\,(i \bmod s + s*(i \operatorname{div} sn))\; *x_1\,((i \operatorname{div} s) \bmod n_1),\ i = 0,\ldots(n_1*n_2)-1$.

32. A method for transmitting and receiving synchronization sequences as claimed in claim 30, wherein a constituent sequence x_2 is composed from two constituent sequences x_3 of *length* n_3 and x_4 of *length* n_4 in accordance with the

formula $x_2(i) = x_4(i \bmod s + s*(i \operatorname{div} sn_3))*x_3((i \operatorname{div} s) \bmod n_3)$, $i = 0,...(n_3*n_4)-1$, or is a Golay sequence.

33. A method for transmitting and receiving synchronization sequences as claimed in claim 31, wherein a constituent sequence x_2 is composed from two constituent sequences x_3 of *length* n_3 and x_4 of *length* n_4 in accordance with the formula $x_2(i) = x_4(i \bmod s + s*(i \operatorname{div} sn_3))*x_3((i \operatorname{div} s) \bmod n_3)$, $i = 0,...(n_3*n_4)-1$, or is a Golay sequence.

REMARKS

The present amendment makes editorial changes and corrects typographical errors in the specification, which includes the Abstract, in order to conform the specification to the requirements of United States Patent Practice. No new matter is added thereby. Attached hereto is a marked-up version of the changes made to the specification by the present amendment. The attached page is captioned "**Version With Markings To Show Changes Made**".

`In addition, the present amendment cancels original claims 1-16 in favor of new claims 17-33. Claims 17-33 have been presented solely because the revisions by crossing out and underlining which would have been necessary in claims 1-16 in order to present those claims in accordance with preferred United States Patent Practice would have been too extensive, and thus would have been too burdensome. The present amendment is intended for clarification purposes only and not for substantial reasons related to patentability pursuant to 35 U.S.C. §§103, 102, 103 or 112. Indeed, the cancellation of claims 1-16 does not constitute an intent on the part of the Applicants to surrender any of the subject matter of claims 1-16.

Early consideration on the merits is respectfully requested.

Respectfully submitted,

______________________ (Reg. No. 39,056)

William E. Vaughan
Bell, Boyd & Lloyd LLC
P.O. Box 1135
Chicago, Illinois 60690-1135
(312) 807-4292
Attorneys for Applicant

10/018436

531 Rec'd PCT/PTO 29 OCT 2001

Version With Markings To Show Changes Made

SPECIFICATION

~~Method for synchronizing a base station with a mobile station, a base station and a mobile station.~~

TITLE OF THE INVENTION

METHOD FOR SYNCHRONIZING A BASE STATION WITH A MOBILE STATION, A BASE STATION AND A MOBILE STATION

BACKGROUND OF THE INVENTION

~~The invention relates to a method for synchronizing a base station with a mobile station, a base station and a mobile station.~~

In signal transmission systems, such as mobile radio systems, it is necessary for one of the communication partners (first transmission unit) to detect specific fixed signals which are emitted by another communication partner (second transmission unit). These can be, for example, what are termed synchronization bursts for synchronizing two synchronization partners such as radio stations, for example, or what are termed access bursts.

In order to detect or identify such received signals reliably by contrast with the ambient noise, it is known to correlate the received signal continuously with a prescribed synchronization sequence over a fixed time duration, and to form the correlation sum over the time duration of the prescribed synchronization sequence. The range of the received signal, which yields a maximum correlation sum, corresponds to the signal being searched for. Connected upstream, as what is termed a training sequence, of the synchronization signal from the base station of a digital mobile radio system~~,~~ is, for example, a synchronization sequence which is detected or determined in the mobile station in the way just described by correlation with the stored synchronization sequence.

Such correlation calculations are also necessary in the base station~~,~~; for example, in the case of random-access-channel (RACH) detection. Moreover, a

correlation calculation is also carried out to determine the channel pulse response and the signal propagation times of received signal bursts.

The correlation sum is calculated as follows in this case:

$$Sm = \sum_{i=0}^{n-1} E(i+m) * K(i)$$

E(i) being a received signal sequence derived from the received signal, and K(i) being the prescribed synchronization sequence, i running from 0 to n-1. The correlation sum Sm is calculated sequentially for a <u>number</u> ~~plurality~~ of temporally offset signal sequences E(i) obtained from the received signal, and then the maximum value of Sm is determined. If k sequential correlation sums are to be calculated, the outlay on calculation is k * n operations, a multiplication and addition being counted together as one operation.

The calculation of the correlation sums is, therefore, very complicated and, particularly in real time applications such as voice communication or video-telephony or in CDMA systems, requires powerful and ~~therefore~~ expensive processors which have a high power consumption during calculation. For example, a known synchronization sequence of length 256 chips (a transmitted bit is also termed a chip in CDMA) is to be determined for the purpose of synchronizing the UMTS mobile radio system, which is being standardized. The sequence is repeated every 2560 chips. Since the mobile station initially operates asynchronously relative to the chip clock, the received signal must be oversampled in order still to retain an adequate signal even given an unfavorable sampling situation. Because of the sampling of the I and Q components, this leads to 256*2560*2*2 = 2621440 operations.

WO 96 39749 A discloses transmitting a synchronization sequence, a chip of the sequence itself being a sequence.

"Srdjan Budisin: Golay Complementary Sequences are Superior to PN Sequences, Proceedings of the International Conference on Systems Engineering,

US, New York, IEEE, Vol.-, 1992, pages 101-104, XP 000319401 ISBN: 0-7803-0734-8" discloses using Golay sequences as an alternative to PN sequences.

It is an ~~the~~ object of the present invention to specify methods for synchronizing a base station with a mobile station, as well as to specify both a base station and a mobile station, which permits synchronization of a base station with a mobile station and which is reliable and favorable in terms of outlay.

~~The object is achieved by means of the features of the independent patent claims. Developments are to be gathered from the subclaims.~~

SUMMARY OF THE INVENTION

In this case, firstly, the present invention is based on the idea of forming what is termed a "hierarchical sequence"; ~~,~~ in particular, a hierarchical synchronization sequence y(i) which is based in accordance with the following relationship on a first constituent sequence x1 of length n1 and a second constituent sequence x2 of length n2:

$$y(i) = x_2(i \bmod n_2) * x_1(i \operatorname{div} n_2) \text{ for } i = 0 \ldots (n_1 * n_2) - 1$$

This design principle of a hierarchical synchronization sequence envisages a repetition of a constituent sequences in their full length, the repetitions being modulated with the value of the corresponding element of the second constituent sequence. It is, thereby, possible to form synchronization sequences which can be determined easily when they are contained in a received signal sequence. Such synchronization sequences have good correlation properties and permit efficient calculation of the correlation in a mobile station. It was possible to show this via ~~by means of~~ complex simulation tools created specifically for this purpose.

Furthermore, the present invention is based on the finding that, in the case of the use of a hierarchical sequence as synchronization sequence which is based on two constituent sequences, it is possible to achieve a further reduction in complexity at the receiving end when at least one constituent sequence itself is a hierarchical sequence.

It is provided in this case that only one repetition of the first half (or another part) of the first constituent sequence is carried out, followed thereupon by the

second half and its repetitions. The repetitions are modulated once again with the value of the corresponding element of the second constituent sequence. A parameter s is introduced which specifies the part of the constituent sequence which is repeated as a coherent piece. The formula describing this generalized developed formulation for forming "generalized hierarchical sequences" runs:

$$x_1(i) = x_4(i \bmod s + s \cdot (i \operatorname{div} sn_3)) \cdot x_3((i \operatorname{div} s) \bmod n_3), \text{ for } i = 0 \ldots n_3 \cdot n_4 - 1$$

For $s=n_4$, this relationship for describing "generalized hierarchical sequences" is equivalent to the relationship explained above for forming "hierarchical synchronization sequences".

Within the scope of the present invention, "constituent sequences" as well as "partial signal sequences" are denoted as K1 and K2, respectively, or as x1 and x_1, respectively, or as x2 and x_2, respectively.~~;~~ "S~~s~~ynchronization sequences" or "synchronization codes" are also denoted as "y(i)" or "K(i)". Of course, "determination of a synchronization sequence" is also understood as the determination of the temporal position of a synchronization sequence. The term "received signal sequence" is also understood as a signal sequence which is derived from a received signal by demodulation, filtering, derotation, scaling or analog-to-digital conversion, for example.

A development of the present invention is based on the finding that, in the case of the use of a hierarchical sequence as synchronization sequence which is based on two constituent sequences, at least one constituent sequence being a Golay sequence, it is possible to achieve a further reduction in complexity at the receiving end.

It was possible through the use of ~~by means of~~ complicated simulations to find parameters for describing Golay sequences which are particularly well suited as constituent sequences.

Specific refinements of the present invention provide for using constituent sequences of length 16 to form a hierarchical 256 chip sequence;~~,~~ in particular, a synchronization sequence, a first constituent sequence being a Golay sequence, and a second constituent sequence being a generalized hierarchical sequence whose

constituent sequences are based on two Golay sequences (of length 4). For example, x_2 is defined as the Golay sequence of length 16 which is obtained by the delay matrix $D^2 = [8, 4, 1,2]$ and the weight matrix $W^2 = [1, -1, 1,1]$. x_1 is a generalized hierarchical sequence, in which case s=2 and the two Golay sequences x_3 and x_4 are used as constituent sequences. x_3 and x_4 are identical and are defined as Golay sequences of length 4 which are described by the delay matrix $D^3 = D^4 = [1, 2]$ and the weight matrix $W^3 = W^4 = [1, 1]$.

A Golay sequence a_N, also denoted as a Golay complementary sequence, can be formed in this case using the following relationship:

$$a_0(k) = \delta(k) \text{ and } b_0(k) = \delta(k)$$

$$a_n(k) = a_{n-1}(k) + W_n \cdot b_{n-1}(k-D_n),$$

$$b_n(k) = a_{n-1}(k) - W_n \cdot b_{n-1}(k-D_n),$$

$$k = 0, 1, 2, \ldots, 2^N,$$

$$n = 1, 2, \ldots, N.$$

$\delta(k)$ Kronecker delta function

D Delay matrix

W Weight matrix

Additional features and advantages of the present invention are described in, and will be apparent from, the following Detailed Description of the Invention and the Figures.

~~The invention is described below in more detail with the aid of various exemplary embodiments, the explanation of which is shown by the following listed figures in which:~~

BRIEF DESCRIPTION OF THE FIGURES

Figure 1 shows a schematic of a mobile radio network.~~;~~

Figure 2 shows a block diagram of a radio station.~~;~~

Figure 3 shows a conventional method for calculating correlation sums.~~;~~

Figures 4, 5, 6, 7 and 8 show block diagrams of efficient Golay correlators in connection with the teachings of the present invention.~~;~~

Figure 9 shows a diagram with simulation results.

DETAILED DESCRIPTION OF THE INVENTION

Illustrated in F~~f~~igure 1 is a cellular mobile radio network such as, for example, the GSM (Global System for Mobile Communication), which includes comprises a multiplicity of mobile switching centers MSC which are networked with one another and/or provide access to a fixed network PSTN/ISDN. Furthermore, these mobile switching centers MSC are connected to, in each case, at least one base station controller BSC, which can also be formed by a data processing system. A similar architecture is also to be found in a UMTS (Universal Mobile Telecommunication System).

Each base station controller BSC is connected, in turn, to at least one base station BS. Such a base station BS is a radio station which can use an air interface to set up a radio link to other radio stations, what are termed mobile stations MS. Information inside radio channels f which are situated inside frequency bands b can be transmitted via ~~by means of~~ radio signals between the mobile stations MS and the base station BS assigned to these mobile stations MS. The range of the radio signals of a base station substantially defines a radio cell FZ.

Base stations BS and a base station controller BSC can be combined to form a base station system BSS. The base station system BSS is also responsible in this case for radio channel management and/or assignment, data rate matching, monitoring the radio transmission link, hand-over procedures and, in the case of a CDMA system, assigning the spread code set to be used, and transfers the signaling information required for this purpose to the mobile stations MS.

For FDD (Frequency-Division Duplex) systems such as the GSM, it is possible in the case of a duplex system to provide for the uplink u (mobile station (transmitting unit) to the base station (receiving unit)) frequency bands differing from those for the downlink d (base station (transmitting unit) to the mobile station (receiving unit)). A number ~~plurality~~ of frequency channels f can be implemented within the different frequency bands b via ~~by means of~~ an FDMA (Frequency-Division Multiple Access) method.

Within the scope of the present application, the transmission unit is also understood as a communication unit, transmitting unit, receiving unit, communication terminal, radio station, mobile station or base station. Terms and examples used within the scope of this application frequently refer also to a GSM mobile radio system; however, they are not in any way limited thereto, but ~~can~~ easily can be mapped by a person skilled in the art with the aid of the description onto other, possibly future, mobile radio systems. Such systems would include, for example, ~~such as~~ CDMA systems;~~,~~ in particular, wide-band CDMA systems.

Data can be efficiently transmitted, separated and assigned to one or more specific links and/or to the appropriate subscriber via an air interface via ~~by means of~~ multiple access methods. It is possible to make use for this purpose of time-division multiple access TDMA, frequency-division multiple access FDMA, code-division multiple access CDMA or a combination of a number ~~plurality~~ of these multiple access methods.

In FDMA, the frequency band b is broken down into a number ~~plurality~~ of frequency channels f.~~;~~ T~~t~~hese frequency channels are split up into time slots ts via ~~by means of~~ time-division multiple access TDMA. The signals transmitted within a time slot ts and a frequency channel f can be separated via spread codes, what are termed CDMA codes cc, that are modulated in a link-specific fashion onto the data.

The physical channels thus produced are assigned to logic channels according to a fixed scheme. The logic channels are basically distinguished into two types: signaling channels (or control channels) for transmitting signaling information (or control information), and traffic channels (TCH) for transmitting useful data.

The signaling channels are further subdivided into:

- broadcast channels
- common control channels
- dedicated/access control channels DCCH/ACCH

The group of broadcast channels includes the broadcast control channel BCCH, through which the MS receives radio information from the base station

system BSS, the frequency correction channel FCCH and the synchronization channel SCH. The common control channels include the random access channel RACH. The bursts or signal sequences that are transmitted to implement these logic channels can include, in this case, for different purposes synchronization sequences K(i), what are termed correlation sequences, or synchronization sequences K(i) can be transmitted on these logic channels for different purposes.

A method for synchronizing a mobile station MS with a base station BS is explained now ~~below~~ by way of example.~~:~~ D~~d~~uring a first step of the initial search for a base station or search for a cell (initial cell search procedure), the mobile station uses the primary synchronization channel (SCH (PSC)) in order to achieve a time slot synchronization with the strongest base station. This can be ensured via ~~by means of~~ a matched filter or an appropriate circuit which is matched to the primary synchronization code cp (synchronization sequence) that is emitted by all the base stations. In this case, all the base stations BS emit the same primary synchronization code cp of length 256.

The mobile station uses correlation to determine from a received sequence the received synchronization sequences K(i). In this case, peaks are output at the output of a matched filter for each received synchronization sequence of each base station located within the reception area of the mobile station. The detection of the position of the strongest peak permits the determination of the timing of the strongest base station modulo of the slot length. In order to ensure a greater reliability, the output of the matched filter can be accumulated over the number of time slots in a non-coherent fashion. The mobile station therefore carries out a correlation over a synchronization sequence of length 256 chips as a matched-filter operation.

The synchronization code cp can be formed in this case according to a hierarchical synchronization sequence K(i) or y(i) using the following relationships from two constituent sequences x_1 and x_2 of length n_1 and n_2 respectively:

$$y(i) = x_2(i \bmod n_2) * x_1(i \operatorname{div} n_2) \text{ for } i = 0 \ldots (n_1 * n_2) - 1$$

The constituent sequences x_1 and x_2 are of length 16 (that is to say, $n_1 = n_2 = 16$), and are defined by the following relationships:

$$x_1(i) = x_4(i \bmod s + s*(i \operatorname{div} sn_3)) * x_3((i \operatorname{div} s) \bmod n_3),\ i = 0 \ldots (n_3 * n_4) - 1$$

$\mathbf{x}_1$ is, thus, a generalized hierarchical sequence using the above formula, in which case s=2 is selected and the two Golay sequences x_3 and x_4 are used as constituent sequences.

$\mathbf{x}_2$ is defined as the Golay sequence of length 16 (N_2=2) which is obtained via ~~by means of~~ the delay matrix $D^2 = [8, 4, 1,2]$ and the weight matrix $W^2 = [1, -1, 1,1]$.

$\mathbf{x}_3$ and x_4 are identical Golay sequences of length 4 (N = 2), which are defined by the delay matrix $D^3 = D^4 = [1, 2]$ and the weight matrix $W^3 = W^4 = [1, 1]$.

The Golay sequences are defined using the following recursive relationship:

$$a_0(k) = \delta(k) \text{ and } b_0(k) = \delta(k)$$

$$a_n(k) = a_{n-1}(k) + W_n \cdot b_{n-1}(k-D_n),$$

$$b_n(k) = a_{n-1}(k) - W_n \cdot b_{n-1}(k-D_n),$$

$$k = 0, 1, 2, \ldots, 2^N,$$

$$n = 1, 2, \ldots, N.$$

$\boldsymbol{a}_N$ then defines the required Golay sequence.

Figure 2 shows a radio station which can be a mobile station MS, which includes ~~consisting of~~ an operating unit or interface unit MMI, a control device STE, a processing device VE, a power supply device SVE, a receiving device EE and, if appropriate, a transmitting device SE.

The control device STE essentially includes ~~comprises~~ a program-controlled microcontroller MC~~,~~ which can access memory chips SPE by writing and reading. The microcontroller MC controls and monitors all essential elements and functions of the radio station.

The processing device VE ~~can~~ also can be formed by a digital signal processor DSP, which can likewise access memory chips SPE. Addition and

multiplication ~~means can~~ also can be achieved via ~~realized by means of~~ the processing device VE.

The microcontroller MC and/or the digital signal processor DSP and/or storage devices SPE and/or further computing elements known as such to a person skilled in the art can be combined in this case to form a processor device which is set up in such a way that the method of the present invention ~~in accordance with claims 1 to 12~~ can be carried out.

The program data required for controlling the radio station and the communication cycle, as well as, in particular, the signaling procedures, and information produced during the processing of signals are stored in the volatile or nonvolatile memory chips SPE. Moreover, synchronization sequences K(i) which are used for correlation purposes, and intermediate results of correlation sum calculations can be stored therein. The synchronization sequences K(i) within the scope of the present invention can, thus, be stored in the mobile station and/or the base station. It is also possible for one or more of parameters for defining synchronization sequences or partial signal sequences or partial signal sequence pairs (K1(j);K2(k)) derived therefrom to be stored in the mobile station and/or the base station. It is also possible for a synchronization sequence K(i) to be formed from a partial signal sequence pair (K1(j);K2(k)) and/or one or more parameters for defining synchronization sequences or partial signal sequences derived therefrom in the mobile station and/or the base station.

In particular, it is possible to store in a base station, or in all the base stations in a system, a synchronization sequence K(i) which is emitted at fixed or variable intervals for synchronization purposes. Constituent sequences (partial signal sequences) or parameters from which the synchronization sequence K(i) stored in the base station can be, or are, formed are stored in the mobile station MS and are used to synchronize the mobile station with a base station in order to calculate the correlation sum favorably in terms of computational outlay.

The storage of the synchronization sequences or the partial signal sequences or parameters ~~can~~ also can be performed by storing appropriate information in arbitrarily coded form, and can be implemented with the aid of ~~means for~~ storage

devices such as, for example, volatile and/or nonvolatile memory chips or via ~~by means of~~ appropriately designed adder or multiplier inputs or appropriate hardware configurations which have the same effect.

The high-frequency section HF includes, ~~comprises,~~ if appropriate, the transmitting device SE, with a modulator and an amplifier V, and a receiving device EE with a demodulator and, likewise, an amplifier. The analog audio signals and the analog signals originating from the receiving device EE are converted via ~~by means of~~ analog-to-digital conversion into digital signals and processed by the digital signal processor DSP. After processing, the digital signals are converted, if appropriate, by digital-to-analog conversion into analog audio signals or other output signals and analog signals that are to be fed to the transmitting device SE. Modulation or demodulation, respectively, is carried out for this purpose, if appropriate.

The transmitting device SE and the receiving device EE are fed with the frequency of a voltage-controlled oscillator VCO via the synthesizer SYN. The system clock for timing processor devices of the radio station ~~can~~ also can be generated via ~~by means of~~ the voltage-controlled oscillator VCO.

An antenna device ANT is provided for receiving and for transmitting signals via the air interface of a mobile radio system. The signals are received and transmitted in what are termed bursts that are pulsed over time in the case of some known mobile radio systems such as the GSM (Global System for Mobile Communication).

The radio station ~~may~~ also may be a base station BS. In this case, the loudspeaker element and the microphone element of the operating unit MMI are replaced by a link to a mobile radio network, for example via a base station controller BSC or a switching device MSC. The base station BS has an appropriate multiplicity of transmitting and receiving devices, respectively, in order to exchange data simultaneously with a number ~~plurality~~ of mobile stations MS.

A received signal sequence E(l), which ~~can~~ also can be a signal sequence derived from a received signal, of length W is illustrated in F~~f~~igure 3. In order to

calculate a first correlation sum S0 in accordance with the formula specified at the beginning, elements of a first section of this received signal sequence E(l) are multiplied in pairs by the corresponding elements of the synchronization sequence K(i) of length n, and the length of the resulting partial results is added to the correlation sum S0.

In order to calculate a further correlation sum S1, as illustrated in the Figure 3 ~~the figure~~, the synchronization sequence K(i) is shifted to the right by one element, and the elements of the synchronization sequence K(i) are multiplied in pairs by the corresponding elements of the signal sequence E(l), and the correlation sum S1 is formed again by summing the partial results produced.

The pairwise multiplication of the elements of the synchronization sequence by corresponding elements of the received signal sequence, and the subsequent summation ~~can~~ also can be described in vector notation as the formation of a scalar product, if the elements of the synchronization sequence and the elements of the received synchronization sequence are respectively combined to form a vector:

$$S0 = \begin{pmatrix} K(0) \\ \vdots \\ K(i) \\ \cdot \\ K(n-1) \end{pmatrix} * \begin{pmatrix} E(0) \\ \cdot \\ E(i) \\ \vdots \\ E(n-1) \end{pmatrix} = K(0) * E(0) + .. + K(i) * E(i) + ... + K(n-1) * E(n-1)$$

$$S1 = \begin{pmatrix} K(0) \\ \vdots \\ K(i) \\ \vdots \\ K(n-1) \end{pmatrix} * \begin{pmatrix} E(1) \\ \vdots \\ E(i+1) \\ \vdots \\ E(n) \end{pmatrix} = K(0) * E(1) + ... + K(i) * E(i+1) + ... + K(n-1) * E(n)$$

In the correlation sums S thus determined, it is possible to search for the maximum and compare the maximum of the correlation sums S with a prescribed threshold value and, thus, determine whether the prescribed synchronization sequence K(i) is included in the received signal E(l) and, if so, where it is located in

the received signal E(l) and thus two radio stations are synchronized with one another or data are detected on to which an individual spread code has been modulated in the form of a synchronization sequence K(i).

Figure 4 shows an efficient hierarchical correlator for synchronization sequences, Golay sequences X,Y of length nx and ny respectively being used as constituent sequences K1, K2. The correlator consists of two series-connected matched filters (F~~f~~igure 4 a) which are respectively formed as efficient Golay correlators. Figure 4 b~~)~~ shows the matched filter for the sequence X, and F~~f~~igure 4 c~~)~~ shows the matched filter for the sequence Y.

The following designations apply in F~~f~~igure 4 b~~)~~:

n = 1, 2, ...NX

ny	length of sequence Y
nx	length of sequence X
NX	with $nx=2^{NX}$
DX_n	$DX_n = 2^{PX_n}$
PX_n	permutation of the numbers {0, 1, 2, ..., NX-1} for the partial signal sequence X
WX_n	weights for the partial signal sequence X from (+1,-1,+i or -i).

The following designations apply in F~~f~~igure 4 c~~)~~:

n = 1, 2, ...NY

ny	length of sequence Y
NY	with $ny=2^{NY}$
DY_n	$DY_n = 2^{PY_n}$
PY_n	permutation of the numbers {0, 1, 2, ..., NY-1} for the partial signal sequence Y
WY_n	weights for the partial signal sequence Y from (+1,-1,+i or -i).

Moreover, the following definitions and designations are valid in this variant design:

$a_n(k)$ and $b_n(k)$ are two complex sequences of length 2^N,

$\delta(k)$ is the Kronecker delta function,

k is an integer representing time,

n is the iteration number,

D_n is the delay,

P_n , $n = 1, 2, \ldots, N$, is an arbitrary permutation of the numbers $\{0, 1, 2, \ldots, N\text{-}1\}$,

W_n can assume the values +1, -1, +i, -i as weights.

The correlation of a Golay sequence of length 2^N can be carried out efficiently as follows:

The sequences $R_a^{(0)}(k)$ and $R_b^{(0)}(k)$ are defined as $R_a^{(0)}(k) = R_b^{(0)}(k) = r(k)$, r(k) being the received signal or the output of another correlation stage.

The following step is executed N times, n running from 1 to N:

Calculate

$$R_a^{(n)}(k) = W^*_n * R_b^{(n-1)}(k) + R_a^{(n-1)}(k- D_n)$$

And

$$R_b^{(n)}(k) = W^*_n * R_b^{(n-1)}(k) + R_a^{(n-1)}(k- D_n)$$

In this case, W^*_n designates the complex conjugate of W_n. If the weights W are real, W^*_n is identical to W_n.

$R_a^{(n)}(k)$ is then the correlation sum to be calculated.

An efficient Golay correlator for a synchronization sequence of length 256 (2^8) chips in the receiver generally has $2^*\cdot 8\text{-}1=15$ complex adders.

With the combination of hierarchical correlation and efficient Golay correlator, a hierarchical code - (described by two constituent sequences X and Y) -

of length 256 ($2^4 \cdot 2^4$) requires only $2 \cdot 4 - 1 + 2 \cdot 4 - 1 = 14$ complex adders (even in the case when use is made of four-valued constituent sequences).

This reduces by 7% the outlay on calculation, which is very high for the primary synchronization in CDMA mobile radio systems, because efficient hierarchical correlators and Golay correlators can be combined. A possible implementation of the overall correlator, an efficient truncated Golay correlator for generalized hierarchical Golay sequences, is shown in F~~f~~igure 5. This is also designated as a truncated Golay correlator, because one of the outputs is truncated in specific stages, and instead of this another output is used as input for the next stage.

The vector D is defined by D = [128, 16, 64, 32, 8, 4, 1, 2] and W = [1, -1, 1, 1, 1, 1, 1, 1]. This correlator requires only 13 additions per calculated correlation sum.

By comparison with a sequence having a simple hierarchical or Golay-supported structure, the generalized hierarchical Golay sequence offers advantages based on more efficient options for calculating the correlation sum with the aid of this Golay sequence. However, simulations exhibit good results with regard to slot synchronization even in the case of relatively high frequency errors.

The hierarchical Golay sequences are compared below with the two simple methods.

Figure 6 shows firstly an efficient correlator for simple hierarchical sequences, and a simple correlation method for the hierarchical correlation.

The hierarchical correlation consists of two concatenated, matched filter blocks which, in each case, carry out a standardized correlation via one of the constituent sequences. It is assumed that the correlation via X_1 (16-symbol accumulation) is carried out before the correlation via X_2 (16-chip accumulation). This is one implementation option, because the two matched filter blocks (enclosed in dashed lines in F~~f~~igure 6) are linear systems which can be connected in any desired sequence. $240 \cdot n$ delay lines with the minimum word length can be implemented in this way since no accumulation is performed in advance and,

therefore, no signal/interference gain is achieved. Here, n designates the oversampling factor, that is to say how many samples are carried out per chip interval.

As already mentioned, one or both of the matched filter blocks ~~can~~ again can be replaced by a correlator for a (generalized) hierarchical sequence or by an efficient Golay correlator (EGC).

Figure 7 shows a simple correlation method for the efficient Golay correlator (EGC) for a simple Golay sequence. The design of an efficient hierarchical Golay correlator corresponds to an efficient correlator for simple hierarchical sequences (see ~~F~~figure 6), with the exception that two adders can be omitted.

Figure 8 now shows an efficient Golay correlator for a generalized hierarchical Golay sequence. The saving of two adders from 15 adders clearly reduces the complexity of the method accordingly.

Figure 9 shows simulation results, the slot-synchronization step having been investigated in a single-path Rayleigh fading channel with 3 km/h for various chip/noise ratios (CNR) without and with frequency errors. It is shown that, by comparison with another synchronization code, designated as S_{new} below, the above-defined synchronization code, designated as GHG below, is just as well suited in practice with regard to the slot-synchronization power. Results are available for the use of averaging with 24 slots. A secondary synchronization channel, which is based on a random selection from 32 symbols, is transmitted in common with the primary synchronization channel (PSC). The graph shows that there is no substantial difference between the synchronization code S_{new} and the generalized hierarchical Golay synchronization code GHG for no frequency error and for a frequency error of 10 kHz.

The proposed synchronization sequence GHG has better autocorrelation properties than S_{old} (dotted curve), particularly in the case of 10 kHz. The graph shows that the synchronization properties of GHG are thus optimal with reference

to the practical use. S_{old} is a hierarchical correlation sequence that is not especially optimized for frequency errors.

The use of the generalized hierarchical Golay sequences for the primary synchronization channel (PSC) thus reduces ~~thusreduces~~ the computational complexity at the receiving end; the complexity is reduced to only 13 additions by comparison with the conventional sequences of 30 additions and/or by comparison with Golay sequences of 15 additions per output sample.

The simulations show that the proposed synchronization sequence GHG have good synchronization properties in the case both of low and of relatively high errors. Because of a lower computational complexity, less specific hardware is required for implementation, and a lower power consumption is achieved.

Although the present invention has been described with reference to specific embodiments, those of skill in the art will recognize that changes may be made thereto without departing from the spirit and scope of the invention as set forth in the hereafter appended claims.

ABSTRACT OF THE DISCLOSURE

~~Abstract~~

Method for forming and/or determining a synchronization sequence, a synchronization method, a transmitting unit and a receiving unit, the formation ~~Formation~~ of synchronization sequences, which are based on partial signal sequences, includes a ~~the~~ second partial signal sequence being repeated and modulated in the process by a ~~the~~ first partial signal sequence.

~~Figure 1~~

Description

Method for synchronizing a base station with a mobile station, a base station and a mobile station

The invention relates to a method for synchronizing a base station with a mobile station, a base station and a mobile station.

In signal transmission systems, such as mobile radio systems, it is necessary for one of the communication partners (first transmission unit) to detect specific fixed signals which are emitted by another communication partner (second transmission unit). These can be, for example, what are termed synchronization bursts for synchronizing two synchronization partners such as radio stations, for example, or what are termed access bursts.

In order to detect or identify such received signals reliably by contrast with the ambient noise, it is known to correlate the received signal continuously with a prescribed synchronization sequence over a fixed time duration, and to form the correlation sum over the time duration of the prescribed synchronization sequence. The range of the received signal, which yields a maximum correlation sum, corresponds to the signal being searched for. Connected upstream, as what is termed a training sequence, of the synchronization signal from the base station of a digital mobile radio system, is, for example, a synchronization sequence which is detected or determined in the mobile station in the way just described by correlation with the stored synchronization sequence.

Such correlation calculations are also necessary in the base station, for example in the case of random-access-channel (RACH) detection. Moreover, a correlation calculation is also carried out to determine the channel pulse response and the signal propagation times of received signal bursts.

The correlation sum is calculated as follows in this case:

$$Sm = \sum_{i=0}^{n-1} E(i+m) * K(i)$$

E(i) being a received signal sequence derived from the received signal, and K(i) being the prescribed synchronization sequence, i running from 0 to n-1. The correlation sum Sm is calculated sequentially for a plurality of temporally offset signal sequences E(i) obtained from the received signal, and then the maximum value of Sm is determined. If k sequential correlation sums are to be calculated, the outlay on calculation is k * n operations, a multiplication and addition being counted together as one operation.

The calculation of the correlation sums is therefore very complicated and, particularly in real time applications such as voice communication or video-telephony or in CDMA systems, requires powerful and therefore expensive processors which have a high power consumption during calculation. For example, a known synchronization sequence of length 256 chips (a transmitted bit is also termed a chip in CDMA) is to be determined for the purpose of synchronizing the UMTS

mobile radio system, which is being standardized. The sequence is repeated every 2560 chips. Since the mobile station initially operates asynchronously relative to the chip clock, the received signal must be oversampled in order still to retain an adequate

signal even given an unfavorable sampling situation. Because of the sampling of the I and Q components, this leads to 256*2560*2*2 = 2621440 operations.

WO 96 39749 A discloses transmitting a synchronization sequence, a chip of the sequence itself being a sequence.

"Srdjan Budisin: Golay Complementary Sequences are Superior to PN Sequences, Proceedings of the International Conference on Systems Engineering, US, New York, IEEE, Vol.-, 1992, pages 101-104, XP 000319401 ISBN: 0-7803-0734-8" discloses using Golay sequences as an alternative to PN sequences.

It is the object of the invention to specify methods for synchronizing a base station with a mobile station, a base station and a mobile station which permits synchronization of a base station with a mobile station which is reliable and favorable in terms of outlay.

The object is achieved by means of the features of the independent patent claims. Developments are to be gathered from the subclaims.

In this case, firstly, the invention is based on the idea of forming what is termed a "hierarchical sequence", in particular a hierarchical synchronization sequence y(i) which is based in accordance with the following relationship on a first constituent sequence x1 of length n1 and a second constituent sequence x2 of length n2:

$$y(i) = x_2(i \bmod n_2) * x_1(i \operatorname{div} n_2) \text{ for } i = 0 \ldots (n_1 * n_2) - 1$$

This design principle of a hierarchical synchronization sequence envisages a repetition of a constituent

sequences in their full length, the repetitions being modulated with the value of the corresponding element of the second constituent sequence. It is thereby possible to form synchronization sequences which can be determined easily when they are contained in a received signal sequence. Such synchronization sequences have good correlation properties and permit efficient calculation of the correlation in a mobile station. It was possible to show this by means of complex simulation tools created specifically for this purpose.

Furthermore, the invention is based on the finding that in the case of the use of a hierarchical sequence as synchronization sequence which is based on two constituent sequences, it is possible to achieve a further reduction in complexity at the receiving end when at least one constituent sequence itself is a hierarchical sequence.

It is provided in this case that only one repetition of the first half (or another part) of the first constituent sequence is carried out, followed thereupon by the second half and its repetitions. The repetitions are modulated once again with the value of the corresponding element of the second constituent sequence. A parameter s is introduced which specifies the part of the constituent sequence which is repeated as a coherent piece. The formula describing this generalized developed formulation for forming "generalized hierarchical sequences" runs:

$$\mathbf{x}_1(i) = x_4(i \bmod s + s\cdot(i \operatorname{div} sn_3))\cdot x_3((i \operatorname{div} s) \bmod n_3),$$
for $i = 0 \ldots n_3 \cdot n_4 - 1$

For $s=n_4$, this relationship for describing "generalized hierarchical sequences" is equivalent to the

relationship explained above for forming "hierarchical synchronization sequences".

Within the scope of the present invention, "constituent sequences" as well as "partial signal sequences" are denoted as K1 and K2, respectively, or as x1 and x_1, respectively, or as x2 and x_2, respectively; "synchronization sequences" or "synchronization codes" are also denoted as "y(i)" or "K(i)". Of course, "determination of a synchronization sequence" is also understood as the determination of the temporal position of a synchronization sequence. The term "received signal sequence" is also understood as a signal sequence which is derived from a received signal by demodulation, filtering, derotation, scaling or analog-to-digital conversion, for example.

A development of the invention is based on the finding that in the case of the use of a hierarchical sequence as synchronization sequence which is based on two constituent sequences, at least one constituent sequence being a Golay sequence, it is possible to achieve a further reduction in complexity at the receiving end.

It was possible by means of complicated simulations to find parameters for describing Golay sequences which are particularly well suited as constituent sequences.

Specific refinements of the invention provide for using constituent sequences of length 16 to form a hierarchical 256 chip sequence, in particular a synchronization sequence, a first constituent sequence being a Golay sequence, and a second constituent sequence being a generalized hierarchical sequence

whose constituent sequences are based on two Golay sequences (of length 4).

For example, x_2 is defined as the Golay sequence of length 16 which is obtained by the delay matrix D^2 = [8, 4, 1,2] and the weight matrix W^2 = [1, -1, 1,1]. x_1 is a generalized hierarchical sequence, in which case s=2 and the two Golay sequences x_3 and x_4 are used as constituent sequences. x_3 and x_4 are identical and are defined as Golay sequences of length 4 which are described by the delay matrix $D^3 = D^4$ = [1, 2] and the weight matrix $W^3 = W^4$ = [1, 1].

A Golay sequence a_N, also denoted as a Golay complementary sequence, can be formed in this case using the following relationship:

$$a_0(k) = \delta(k) \text{ and } b_0(k) = \delta(k)$$

$$a_n(k) = a_{n-1}(k) + W_n \cdot b_{n-1}(k-D_n),$$

$$b_n(k) = a_{n-1}(k) - W_n \cdot b_{n-1}(k-D_n),$$

$$k = 0, 1, 2, \ldots, 2^N,$$

$$n = 1, 2, \ldots, N.$$

$\delta(k)$ Kronecker delta function

D Delay matrix

W Weight matrix

The invention is described below in more detail with the aid of various exemplary embodiments, the explanation of which is shown by the following listed figures in which:

Figure 1 shows a schematic of a mobile radio network;

Figure 2 shows a block diagram of a radio station;

Figure 3 shows a conventional method for calculating correlation sums;

Figures 4, 5, 6, 7 and 8
show block diagrams of efficient Golay correlators;

Figure 9 shows a diagram with simulation results.

Illustrated in figure 1 is a cellular mobile radio network such as, for example, the GSM (Global System for Mobile Communication), which comprises a multiplicity of mobile switching centers MSC which are networked with one another and/or provide access to a fixed network PSTN/ISDN. Furthermore, these mobile switching centers MSC are connected to in each case at least one base station controller BSC, which can also be formed by a data processing system. A similar architecture is also to be found in a UMTS (Universal Mobile Telecommunication System).

Each base station controller BSC is connected, in turn, to at least one base station BS. Such a base station BS is a radio station which can use an air interface to set up a radio link to other radio stations, what are termed mobile stations MS. Information inside radio channels f which are situated inside frequency bands b can be transmitted by means of radio signals between the mobile stations MS and the base station BS assigned to these mobile stations MS. The range of the radio signals of a base station substantially defines a radio cell FZ.

Base stations BS and a base station controller BSC can be combined to form a base station system BSS. The base station system BSS is also responsible in this case for radio channel management and/or assignment, data rate matching, monitoring the radio transmission link, hand-over procedures and, in the case of a CDMA system, assigning the spread code set to be used, and transfers the signaling information required for this purpose to the mobile stations MS.

For FDD (Frequency-Division Duplex) systems such as the GSM, it is possible in the case of a duplex system to provide for the uplink u (mobile station (transmitting unit) to the base station (receiving unit)) frequency bands differing from those for the downlink d (base station (transmitting unit) to the mobile station (receiving unit)). A plurality of frequency channels f can be implemented within the different frequency bands b by means of an FDMA (Frequency-Division Multiple Access) method.

Within the scope of the present application, the transmission unit is also understood as a communication unit, transmitting unit, receiving unit, communication terminal, radio station, mobile station or base station. Terms and examples used within the scope of this application frequently refer also to a GSM mobile radio system; however, they are not in any way limited thereto, but can easily be mapped by a person skilled in the art with the aid of the description onto other, possibly future, mobile radio systems such as CDMA systems, in particular wide-band CDMA systems.

Data can be efficiently transmitted, separated and assigned to one or more specific links and/or to the

appropriate subscriber via an air interface by means of multiple access methods. It is possible to make use for this purpose of time-division multiple access TDMA, frequency-division multiple access FDMA,

code-division multiple access CDMA or a combination of a plurality of these multiple access methods.

In FDMA, the frequency band b is broken down into a plurality of frequency channels f; these frequency channels are split up into time slots ts by means of time-division multiple access TDMA. The signals transmitted within a time slot ts and a frequency channel f can be separated by means of spread codes, what are termed CDMA codes cc, that are modulated in a link-specific fashion onto the data.

The physical channels thus produced are assigned to logic channels according to a fixed scheme. The logic channels are basically distinguished into two types: signaling channels (or control channels) for transmitting signaling information (or control information), and traffic channels (TCH) for transmitting useful data.
The signaling channels are further subdivided into:
- broadcast channels
- common control channels
- dedicated/access control channels DCCH/ACCH

The group of broadcast channels includes the broadcast control channel BCCH, through which the MS receives radio information from the base station system BSS, the frequency correction channel FCCH and the synchronization channel SCH. The common control channels include the random access channel RACH. The bursts or signal sequences that are transmitted to implement these logic channels can include in this case for different purposes synchronization sequences K(i), what are termed correlation sequences, or synchronization sequences K(i) can be transmitted on these logic channels for different purposes.

A method for synchronizing a mobile station MS with a base station BS is explained below by way of example: during a first step of the initial search for a base station or search for a cell (initial cell search procedure), the mobile station uses the primary synchronization channel (SCH (PSC)) in order to achieve a time slot synchronization with the strongest base station. This can be ensured by means of a matched filter or an appropriate circuit which is matched to the primary synchronization code cp (synchronization sequence) that is emitted by all the base stations. In this case, all the base stations BS emit the same primary synchronization code cp of length 256.

The mobile station uses correlation to determine from a received sequence the received synchronization sequences K(i). In this case, peaks are output at the output of a matched filter for each received synchronization sequence of each base station located within the reception area of the mobile station. The detection of the position of the strongest peak permits the determination of the timing of the strongest base station modulo of the slot length. In order to ensure a greater reliability, the output of the matched filter can be accumulated over the number of time slots in a non-coherent fashion. The mobile station therefore carries out a correlation over a synchronization sequence of length 256 chips as a matched-filter operation.

The synchronization code cp can be formed in this case according to a hierarchical synchronization sequence K(i) or y(i) using the following relationships from two

constituent sequences x_1 and x_2 of length n_1 and n_2 respectively:

$$y(i) = x_2(i \bmod n_2) * x_1(i \operatorname{div} n_2) \text{ for } i = 0 \ldots (n_1 * n_2) - 1$$

The constituent sequences x_1 and x_2 are of length 16 (that is to say $n_1 = n_2 = 16$), and are defined by the following relationships:

$x_1(i) = x_4(i \bmod s + s*(i \text{ div } sn_3)) * x_3((i \text{ div } s) \bmod n_3)$, $i = 0 \ldots (n_3 * n_4) - 1$

$\mathbf{x}_1$ is thus a generalized hierarchical sequence using the above formula, in which case s=2 is selected and the two Golay sequences x_3 and x_4 are used as constituent sequences.

$\mathbf{x}_2$ is defined as the Golay sequence of length 16 (N_2=2) which is obtained by means of the delay matrix D^2 = [8, 4, 1,2] and the weight matrix W^2 = [1, -1, 1,1].

$\mathbf{x}_3$ and x_4 are identical Golay sequences of length 4 (N = 2), which are defined by the delay matrix $D^3 = D^4$ = [1, 2] and the weight matrix $W^3 = W^4$ = [1, 1].

The Golay sequences are defined using the following recursive relationship:

$$a_0(k) = \delta\ (k) \text{ and } b_0\ (k) = \delta\ (k)$$

$$a_n\ (k) = a_{n-1}(k) + W_n \cdot b_{n-1}(k-D_n)\ ,$$

$$b_n\ (k) = a_{n-1}(k) - W_n \cdot b_{n-1}(k-D_n)\ ,$$

$$k = 0,\ 1,\ 2,\ \ldots,\ 2^N,$$

$$n = 1,\ 2,\ \ldots,\ N.$$

$\mathbf{a}_N$ then defines the required Golay sequence.

Figure 2 shows a radio station which can be a mobile station MS, consisting of an operating unit or interface unit MMI, a control device STE, a processing device VE, a power supply device SVE, a receiving device EE and, if appropriate, a transmitting device SE.

The control device STE essentially comprises a program-controlled microcontroller MC, which can access memory chips SPE by writing and reading. The microcontroller MC controls and monitors all essential elements and functions of the radio station.

The processing device VE can also be formed by a digital signal processor DSP, which can likewise access memory chips SPE. Addition and multiplication means can also be realized by means of the processing device VE.

The microcontroller MC and/or the digital signal processor DSP and/or storage devices SPE and/or further computing elements known as such to a person skilled in the art can be combined in this case to form a processor device which is set up in such a way that the method in accordance with claims 1 to 12 can be carried out.

The program data required for controlling the radio station and the communication cycle, as well as, in particular, the signaling procedures, and information produced during the processing of signals are stored in the volatile or nonvolatile memory chips SPE. Moreover, synchronization sequences K(i) which are used for correlation purposes, and intermediate results of

correlation sum calculations can be stored therein. The synchronization sequences K(i) within the scope of the invention can thus be stored in the mobile station and/or the base station. It is also possible for one or more of parameters for defining synchronization sequences or partial signal sequences or partial signal sequence pairs (K1(j);K2(k)) derived therefrom to be stored in the mobile station and/or the base station. It is also possible for a synchronization sequence K(i) to be formed from a partial signal sequence pair (K1(j);K2(k)) and/or one or more parameters for defining synchronization sequences or partial signal sequences derived therefrom in the mobile station and/or the base station.

In particular, it is possible to store in a base station or in all the base stations in a system a synchronization sequence K(i) which is emitted at fixed or variable intervals for synchronization purposes. Constituent sequences (partial signal sequences) or parameters from which the synchronization sequence K(i) stored in the base station can be or are, formed are stored in the mobile station MS and are used to synchronize the mobile station with a base station in order to calculate the correlation sum favorably in terms of computational outlay.

The storage of the synchronization sequences or the partial signal sequences or parameters can also be performed by storing appropriate information in arbitrarily coded form, and can be implemented with the aid of means for storage such as, for example, volatile and/or nonvolatile memory chips or by means of appropriately designed adder or multiplier inputs or appropriate hardware configurations which have the same effect.

The high-frequency section HF comprises, if appropriate, the transmitting device SE, with a modulator and an amplifier V, and a receiving device EE with a demodulator and, likewise, an amplifier. The analog audio signals and the analog signals originating from the receiving device EE are converted by means of analog-to-digital conversion into digital signals and processed by the digital signal processor DSP. After processing, the digital signals are converted, if appropriate, by digital-to-analog conversion into analog audio signals or other output signals and analog signals that are to be fed to the transmitting device SE. Modulation or demodulation, respectively, is carried out for this purpose, if appropriate.

The transmitting device SE and the receiving device EE are fed with the frequency of a voltage-controlled oscillator VCO via the synthesizer SYN. The system clock for timing processor devices of the radio station can also be generated by means of the voltage-controlled oscillator VCO.

An antenna device ANT is provided for receiving and for transmitting signals via the air interface of a mobile radio system. The signals are received and transmitted in what are termed bursts that are pulsed over time in the case of some known mobile radio systems such as the GSM (Global System for Mobile Communication).

The radio station may also be a base station BS. In this case, the loudspeaker element and the microphone element of the operating unit MMI are replaced by a link to a mobile radio network, for example via a base station controller BSC or a switching device MSC. The base station BS has an appropriate multiplicity of

transmitting and receiving devices, respectively, in order to exchange data simultaneously with a plurality of mobile stations MS.

A received signal sequence E(l), which can also be a signal sequence derived from a received signal, of length W is illustrated in figure 3. In order to calculate a first correlation sum S0 in accordance with the formula specified at the beginning, elements of a first section of this received signal sequence E(l) are multiplied in pairs by the corresponding elements of the synchronization sequence K(i) of length n, and the length of the resulting partial results is added to the correlation sum S0.

In order to calculate a further correlation sum S1, as illustrated in the figure, the synchronization sequence K(i) is shifted to the right by one element, and the elements of the synchronization sequence K(i) are multiplied in pairs by the corresponding elements of the signal sequence E(l), and the correlation sum S1 is formed again by summing the partial results produced.

The pairwise multiplication of the elements of the synchronization sequence by corresponding elements of the received signal sequence, and the subsequent summation can also be described in vector notation as the formation of a scalar product, if the elements of the synchronization sequence and the elements of the received synchronization sequence are respectively combined to form a vector:

$$S0 = \begin{pmatrix} K(0) \\ \vdots \\ K(i) \\ \vdots \\ K(n-1) \end{pmatrix} * \begin{pmatrix} E(0) \\ \vdots \\ E(i) \\ \vdots \\ E(n-1) \end{pmatrix} = K(0) * E(0) + \ldots + K(i) * E(i) + \ldots + K(n-1) * E(n-1)$$

$$S1 = \begin{pmatrix} K(0) \\ \vdots \\ K(i) \\ \vdots \\ K(n-1) \end{pmatrix} * \begin{pmatrix} E(1) \\ \vdots \\ E(i+1) \\ \vdots \\ E(n) \end{pmatrix} = K(0) * E(1) + \ldots + K(i) * E(i+1) + \ldots + K(n-1) * E(n)$$

In the correlation sums S thus determined, it is possible to search for the maximum and compare the maximum of the correlation sums S with a prescribed threshold value and thus determine whether the prescribed synchronization sequence K(i) is included in the received signal E(l) and if so where it is located in the received signal E(l) and thus two radio stations are synchronized with one another or data are detected on to which an individual spread code has been modulated in the form of a synchronization sequence K(i).

Figure 4 shows an efficient hierarchical correlator for synchronization sequences, Golay sequences X,Y of length nx and ny respectively being used as constituent sequences K1, K2. The correlator consists of two series-connected matched filters (figure 4 a) which are respectively formed as efficient Golay correlators. Figure 4 b) shows the matched filter for the sequence X, and figure 4 c) shows the matched filter for the sequence Y.

The following designations apply in figure 4 b):

n = 1, 2, ...NX

ny length of sequence Y

nx length of sequence X

NX with $nx=2^{NX}$

DX_n $DX_n = \mathbf{2}^{PX_n}$

PX_n permutation of the numbers $\{0, 1, 2, \ldots, NX-1\}$ for the partial signal sequence X

WX_n weights for the partial signal sequence X from (+1,-1,+i or -i).

The following designations apply in figure 4 c):

n = 1, 2, ...NY
ny length of sequence Y
NY with $ny=2^{NY}$
DY_n $DY_n = \mathbf{2}^{PY_n}$
PY_n permutation of the numbers $\{0, 1, 2, ..., NY\text{-}1\}$ for the partial signal sequence Y
WY_n weights for the partial signal sequence Y from (+1,-1,+i or -i).

Moreover, the following definitions and designations are valid in this variant design:

$a_n(k)$ and $b_n(k)$ are two complex sequences of length 2^N,
$\delta(k)$ is the Kronecker delta function,
k is an integer representing time,
n is the iteration number,
D_n is the delay,
P_n , n = 1, 2, ..., N, is an arbitrary permutation of the numbers $\{0, 1, 2, ..., N\text{-}1\}$,
W_n can assume the values +1, -1, +i, -i as weights.

The correlation of a Golay sequence of length 2^N can be carried out efficiently as follows:
The sequences $R_a^{(0)}(k)$ and $R_b^{(0)}(k)$ are defined as $R_a^{(0)}(k) = R_b^{(0)}(k) = r(k)$, r(k) being the received signal or the output of another correlation stage.

The following step is executed N times, n running from 1 to N:

Calculate

$R_a^{(n)}(k) = W^*_n * R_b^{(n-1)}(k) + R_a^{(n-1)}(k - D_n)$

And

$R_b^{(n)}(k) = W^*_n * R_b^{(n-1)}(k) + R_a^{(n-1)}(k - D_n)$

In this case, W^*_n designates the complex conjugate of W_n. If the weights W are real, W^*_n is identical to W_n.

$R_a^{(n)}(k)$ is then the correlation sum to be calculated.

An efficient Golay correlator for a synchronization sequence of length 256 (2^8) chips in the receiver generally has 2*·8-1=15 complex adders.

With the combination of hierarchical correlation and efficient Golay correlator, a hierarchical code - described by two constituent sequences X and Y - of length 256 ($2^4 \cdot 2^4$) requires only 2·4-1+2·4-1 = 14 complex adders (even in the case when use is made of four-valued constituent sequences).

This reduces by 7% the outlay on calculation, which is very high for the primary synchronization in CDMA mobile radio systems, because efficient hierarchical correlators and Golay correlators can be combined. A possible implementation of the overall correlator, an efficient truncated Golay correlator for generalized hierarchical Golay sequences, is shown in figure 5. This is also designated as a truncated Golay correlator, because one of the outputs is truncated in specific stages, and instead of this another output is used as input for the next stage.

The vector D is defined by D = [128, 16, 64, 32, 8, 4, 1, 2] and W = [1, -1, 1, 1, 1, 1, 1, 1]. This correlator requires only 13 additions per calculated correlation sum.

By comparison with a sequence having a simple hierarchical or Golay-supported structure, the generalized hierarchical Golay sequence offers advantages based on more efficient options for calculating the correlation sum with the aid of this Golay sequence. However, simulations exhibit good results with regard to slot synchronization even in the case of relatively high frequency errors.

The hierarchical Golay sequences are compared below with the two simple methods.

Figure 6 shows firstly an efficient correlator for simple hierarchical sequences, and a simple correlation method for the hierarchical correlation.

The hierarchical correlation consists of two concatenated, matched filter blocks which in each case carry out a standardized correlation via one of the constituent sequences. It is assumed that the correlation via X_1 (16-symbol accumulation) is carried out before the correlation via X_2 (16-chip accumulation). This is one implementation option, because the two matched filter blocks (enclosed in dashed lines in figure 6) are linear systems which can be connected in any desired sequence. 240·n delay lines with the minimum word length can be implemented in this way since no accumulation is performed in advance and therefore no signal/interference gain is achieved.

Here, n designates the oversampling factor, that is to say how many samples are carried out per chip interval.

As already mentioned, one or both of the matched filter blocks can again be replaced by a correlator for a (generalized) hierarchical sequence or by an efficient Golay correlator (EGC).

Figure 7 shows a simple correlation method for the efficient Golay correlator (EGC) for a simple Golay sequence. The design of an efficient hierarchical Golay correlator corresponds to an efficient correlator for simple hierarchical sequences (see figure 6), with the exception that two adders can be omitted.

Figure 8 now shows an efficient Golay correlator for a generalized hierarchical Golay sequence. The saving of two adders from 15 adders clearly reduces the complexity of the method accordingly.

Figure 9 shows simulation results, the slot-synchronization step having been investigated in a single-path Rayleigh fading channel with 3 km/h for various chip/noise ratios (CNR) without and with frequency errors. It is shown that, by comparison with another synchronization code, designated as S_{new} below, the above-defined synchronization code, designated as GHG below, is just as well suited in practice with regard to the slot-synchronization power. Results are available for the use of averaging with 24 slots. A secondary synchronization channel, which is based on a random selection from 32 symbols, is transmitted in common with the primary synchronization channel (PSC). The graph shows that there is no substantial difference between the synchronization code S_{new} and the generalized hierarchical Golay synchronization code GHG

for no frequency error and for a frequency error of 10 kHz.

The proposed synchronization sequence GHG has better autocorrelation properties than S_{old} (dotted curve), particularly in the case of 10 kHz. The graph shows that the synchronization properties of GHG are thus optimal with reference to the practical use. S_{old} is a hierarchical correlation sequence that is not especially optimized for frequency errors.

The use of the generalized hierarchical Golay sequences for the primary synchronization channel (PSC) thusreduces the computational complexity at the receiving end; the complexity is reduced to only 13 additions by comparison with the conventional sequences of 30 additions and/or by comparison with Golay sequences of 15 additions per output sample.

The simulations show that the proposed synchronization sequence GHG have good synchronization properties in the case both of low and of relatively high errors. Because of a lower computational complexity, less specific hardware is required for implementation, and a lower power consumption is achieved.

Patent claims

1. A method for synchronizing a base station (BS) with a mobile station (MS), in which the base station (BS) emits a synchronization sequence y(i) of length n which can be formed in accordance with the following relationship from a first constituent sequence x1 of length n1 and a second constituent sequence x2 of length n2:
$y(i) = x_2(i \bmod n_2) * x_1(i \operatorname{div} n_2)$ for $i = 0 \ldots (n_1 * n_2) - 1$,
it being possible to form at least one constituent sequence x_1 or x_2 in accordance with the following relationship from a third constituent sequence x3 of length n3 and a fourth constituent sequence x4 of length n4:
$x_1(i) = x_4(i \bmod s + s*(i \operatorname{div} sn_3)) * x_3((i \operatorname{div} s) \bmod n_3), i = 0 \ldots (n_3 * n_4) - 1;$
or
$x_2(i) = x_4(i \bmod s + s*(i \operatorname{div} sn_3)) * x_3((i \operatorname{div} s) \bmod n_3), i = 0 \ldots (n_3 * n_4) - 1.$

2. The method as claimed in claim 1, in which the synchronization sequence y(i) is of length 256, and the constituent sequences x1, x2 are of length 16.

3. The method as claimed in one of the preceding claims, in which at least one of the constituent sequences x1 or x2 is a Golay sequence.

4. The method as claimed in claim 3, in which at least one of the two constituent sequences x_1 or x_2 is a Golay sequence which is based on the following parameters:

delay matrix D^1 = [8, 4, 1,2] and weight matrix W^1 = [1, -1, 1,1];

or

delay matrix D^2 = [8, 4, 1,2] and weight matrix W^2 = [1, -1, 1,1].

5. The method as claimed in one of the preceding claims, in which x_3 and x_4 are identical Golay sequences of length 4 and are based on the following parameters:
delay matrix $D^3 = D^4$ = [1, 2] and weight matrix $W^3 = W^4$ = [1,1].

6. The method as claimed in one of claims 3 to 5, in which a Golay sequence a_N is defined by the following recursive relationship:

$$a_0(k) = \delta(k) \text{ and } b_0(k) = \delta(k)$$

$$a_n(k) = a_{n-1}(k) + W_n \cdot b_{n-1}(k-D_n),$$

$$b_n(k) = a_{n-1}(k) - W_n \cdot b_{n-1}(k-D_n),$$

$$k = 0, 1, 2, \ldots, 2^N,$$

$$n = 1, 2, \ldots, N,$$

$\delta(k)$ *Kronecker delta function*

7. The method as claimed in one of the preceding claims, in which the synchronization sequence y(i) is received by a mobile station and processed for synchronization purposes.

8. The method as claimed in one of the preceding claims, in which in order to determine a prescribed synchronization

sequence y(i) contained in a received signal sequence E(l), correlation sums S of the synchronization sequence y(i) are determined in the mobile station (MS) with the aid of corresponding sections of the received signal sequence E(l).

9. The method as claimed in claim 8, in which at least one efficient Golay correlator (EGC) is used to determine at least one correlation sum S.

10. A transmitting unit (BS), having means (SPE) for storing or forming a synchronization sequence y(i), which can be formed in accordance with the following relationship from a first constituent sequence x1 of length n1 and a second constituent sequence x2 of length n2:

$y(i) = x_2(i \bmod n_2) * x_1(i \operatorname{div} n_2)$ for $i = 0 \ldots (n_1 * n_2) - 1$,

it being possible to form at least one constituent sequence x_1 or x_2 in accordance with the following relationship from a third constituent sequence x3 of length n3 and a fourth constituent sequence x4 of length n4:

$x_1(i) = x_4(i \bmod s + s*(i \operatorname{div} sn_3)) * x_3((i \operatorname{div} s) \bmod n_3)$, $i = 0 \ldots (n_3 * n_4) - 1$;

or

$x_2(i) = x_4(i \bmod s + s*(i \operatorname{div} sn_3)) * x_3((i \operatorname{div} s) \bmod n_3)$, $i = 0 \ldots (n_3 * n_4) - 1$,

and having means for emitting this synchronization sequence y(i) for the purpose of synchronization with a receiving unit (MS).

11. A mobile station (MS), having means for receiving a received signal sequence E(l), having means for

determining a signal sequence y(i), which can be formed in accordance with the following relationship from a first constituent sequence x1 of length n1 and a second constituent sequence x2 of length n2:

$y(i) = x_2(i \bmod n_2) * x_1(i \operatorname{div} n_2)$ for $i = 0 \ldots (n_1 * n_2) - 1$,

it being possible to form at least one constituent sequence x_1 or x_2 in accordance with the following relationship from a third constituent sequence x3 of length n3 and a fourth constituent sequence x4 of length n4:

$x_1(i) = x_4(i \bmod s + s*(i \operatorname{div} sn_3)) * x_3((i \operatorname{div} s) \bmod n_3)$, $i = 0 \ldots (n_3 * n_4) - 1$;

or

$x_2(i) = x_4(i \bmod s + s*(i \operatorname{div} sn_3)) * x_3((i \operatorname{div} s) \bmod n_3)$, $i = 0 \ldots (n_3 * n_4) - 1$.

12. The mobile station (MS) as claimed in claim 11, having at least one efficient Golay correlator for determining the synchronization sequence y(i).

13. The mobile station (MS) as claimed in one of claims 11 or 12, having two series-connected matched filters which are designed as efficient Golay correlators for the purpose of determining the synchronization sequence y(i).

14. A method for transmitting and/or receiving synchronization sequences, in which the synchronization sequence is composed from two constituent sequences, the first constituent sequence being repeated in accordance with the number of the elements of the second constituent sequence, all the elements of a specific repetition of the first constituent sequence being modulated with the corresponding element of the second constituent sequences, and the repetitions of the first constituent sequence being mutually interleaved.

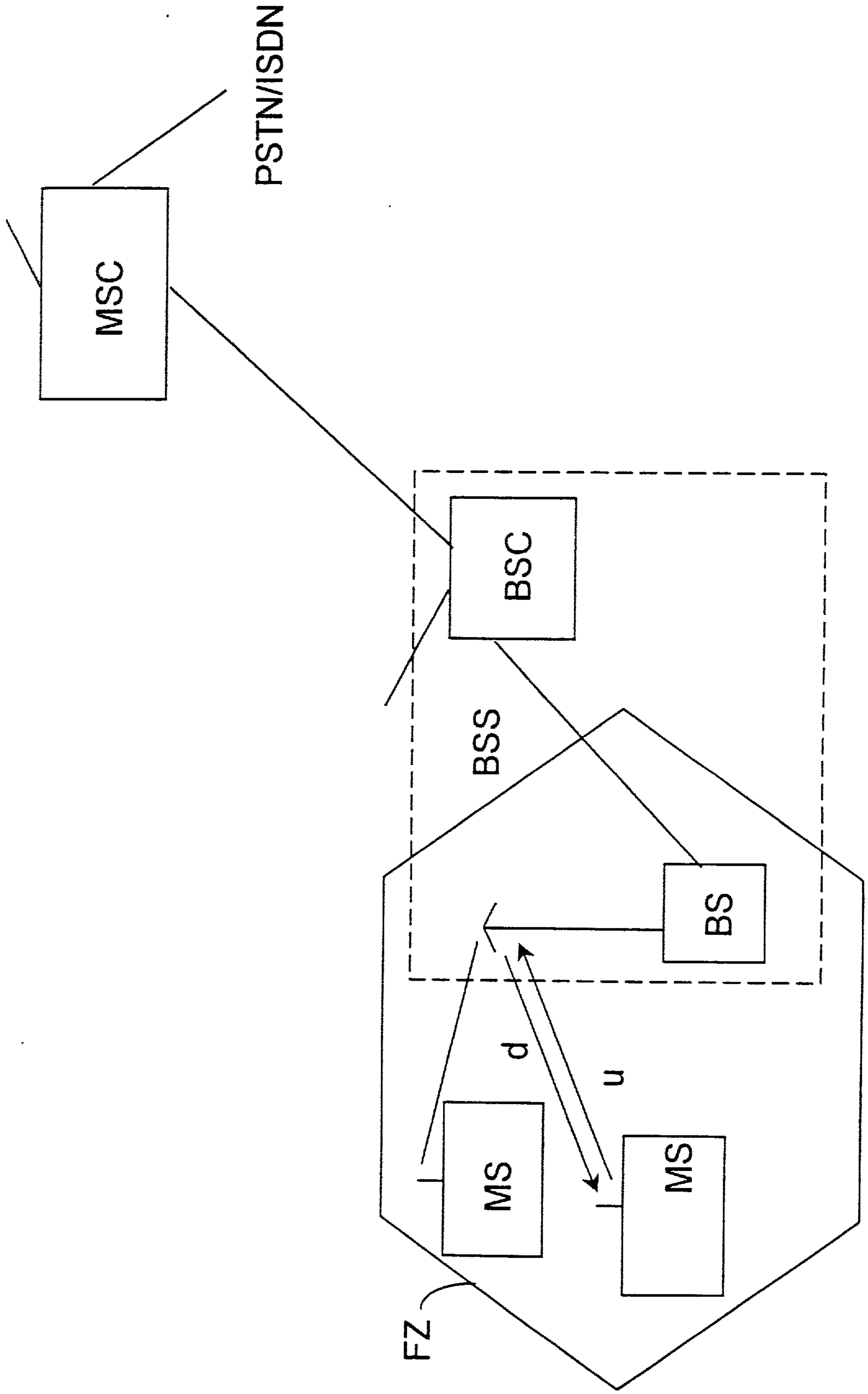
15. A method for transmitting and/or receiving synchronization sequences,

in which the synchronization sequence *y(i) of length* $(n_1 * n_2)$ are composed from two constituent sequences x_1 and x_2 *of length* n_1 and n_2 in accordance with the formula $y(i) = x_2\ (i \bmod s + s*(i \operatorname{div} sn))\ *x_1\ ((i \operatorname{div} s) \bmod n_1),\ i = 0,\ldots(n_1*n_2) - 1$.

16. The method for transmitting and/or receiving synchronization sequences as claimed in one of claims 14 or 15, in which a constituent sequence x_2 is composed from two constituent sequences x_3 of *length* n_3 and x_4 of *length* n_4 in accordance with the formula $x_2(i) = x_4(i \bmod s + s*(i \operatorname{div} sn_3))*x_3\ ((i \operatorname{div} s) \bmod n_3),\ i = 0,\ldots(n_3*n_4) - 1$, or is a Golay sequence.

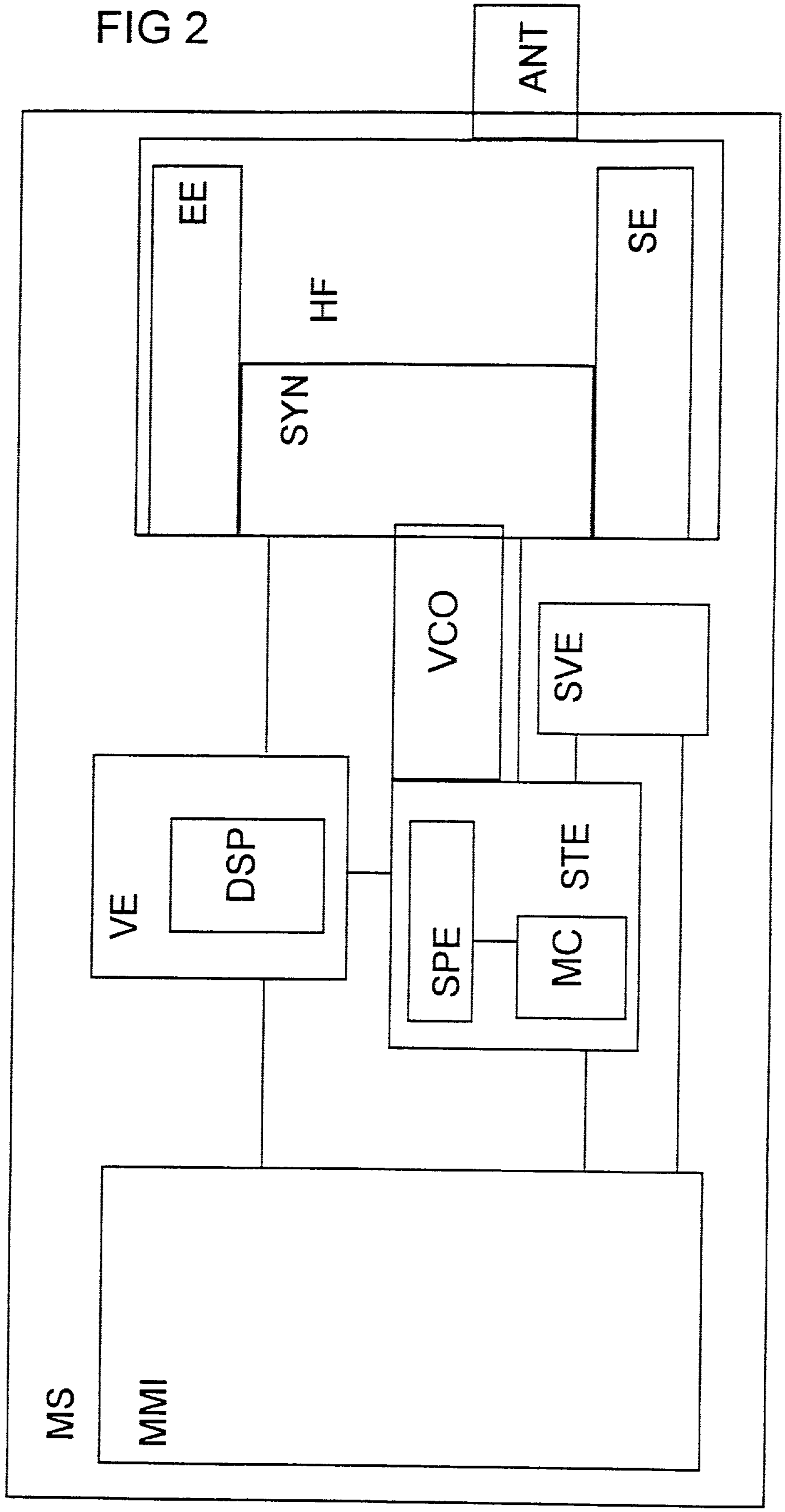
10/018436

FIG 1



10/018436

FIG 2



10/018436

FIG 3

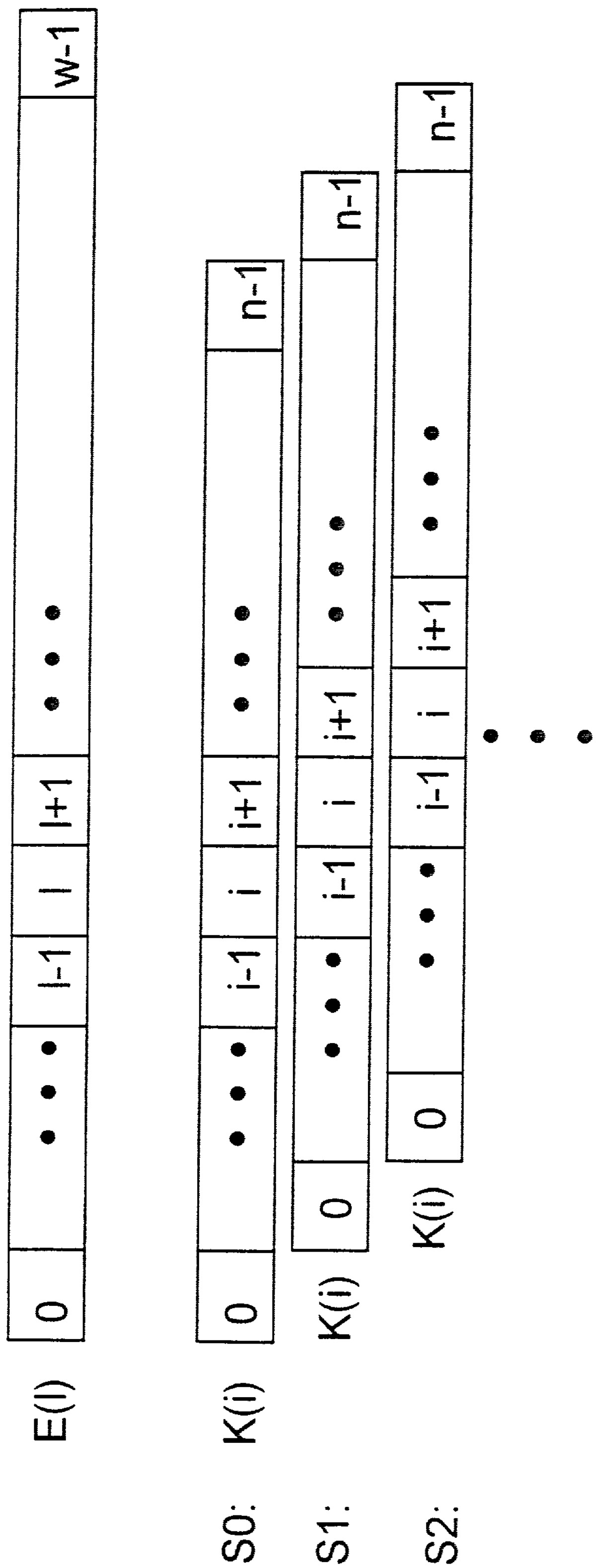
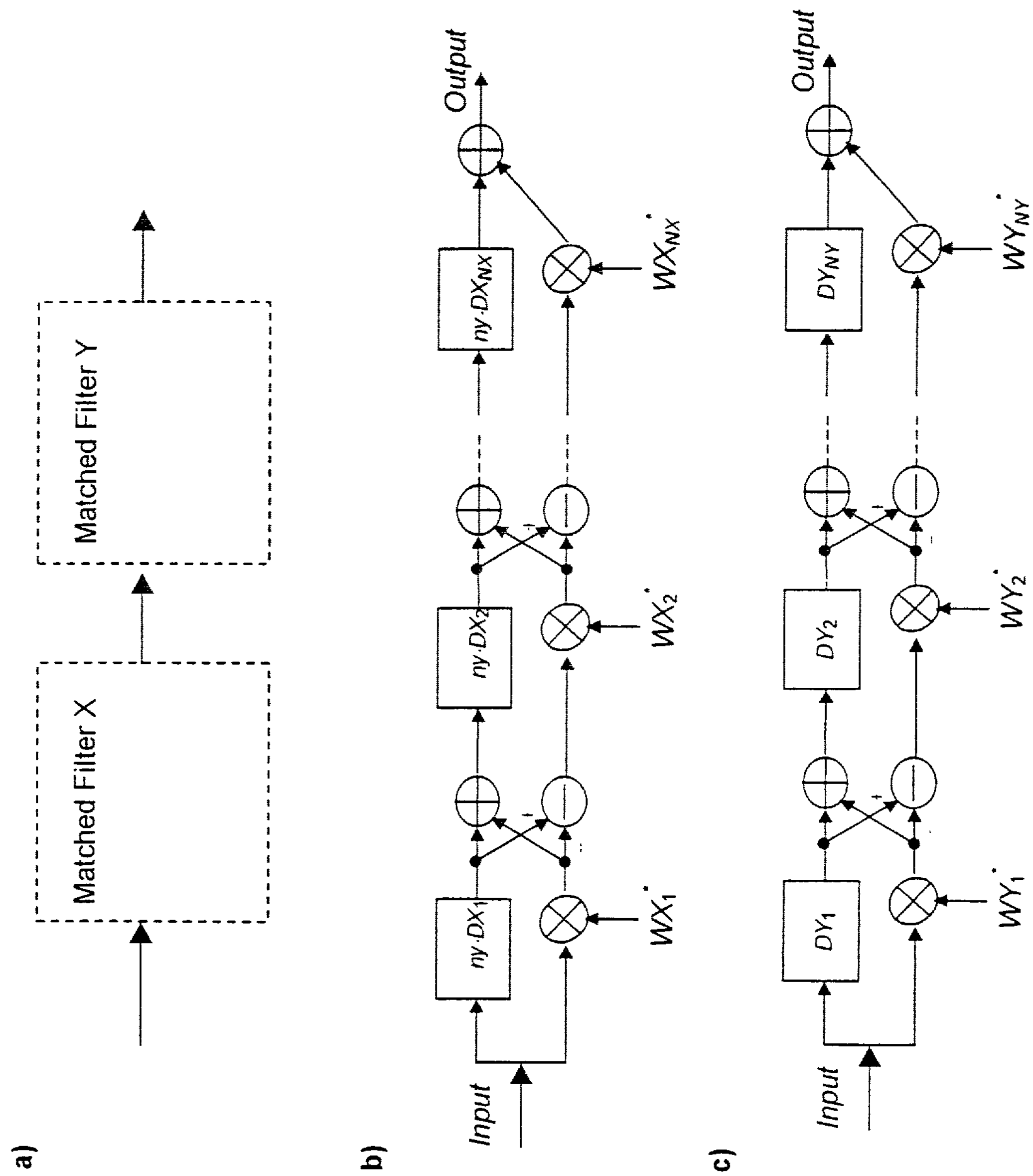


FIG 4


a)
Matched Filter X
Matched Filter Y
b)
Input
$ny \cdot DX_1$
$ny \cdot DX_2$
$ny \cdot DX_{NX}$
WX_1^*
WX_2^*
WX_{NX}^*
Output
c)
Input
DY_1
DY_2
DY_{NY}
WY_1^*
WY_2^*
WY_{NY}^*
Output

10/018436

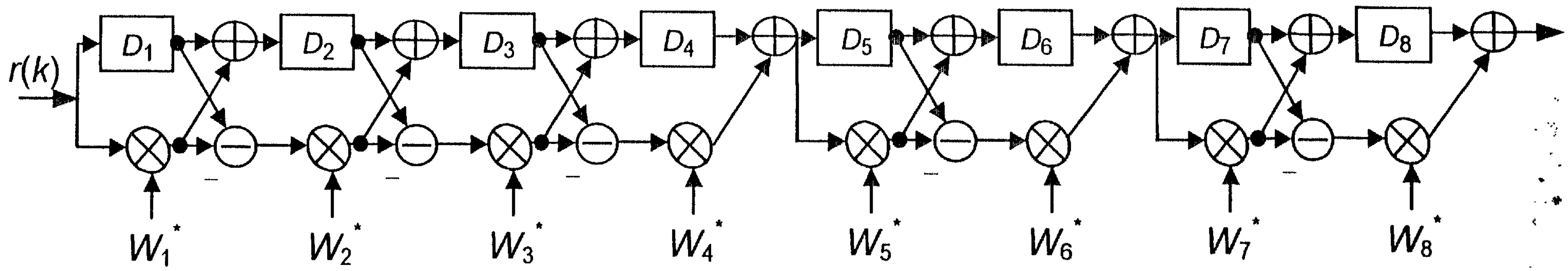


Fig 5

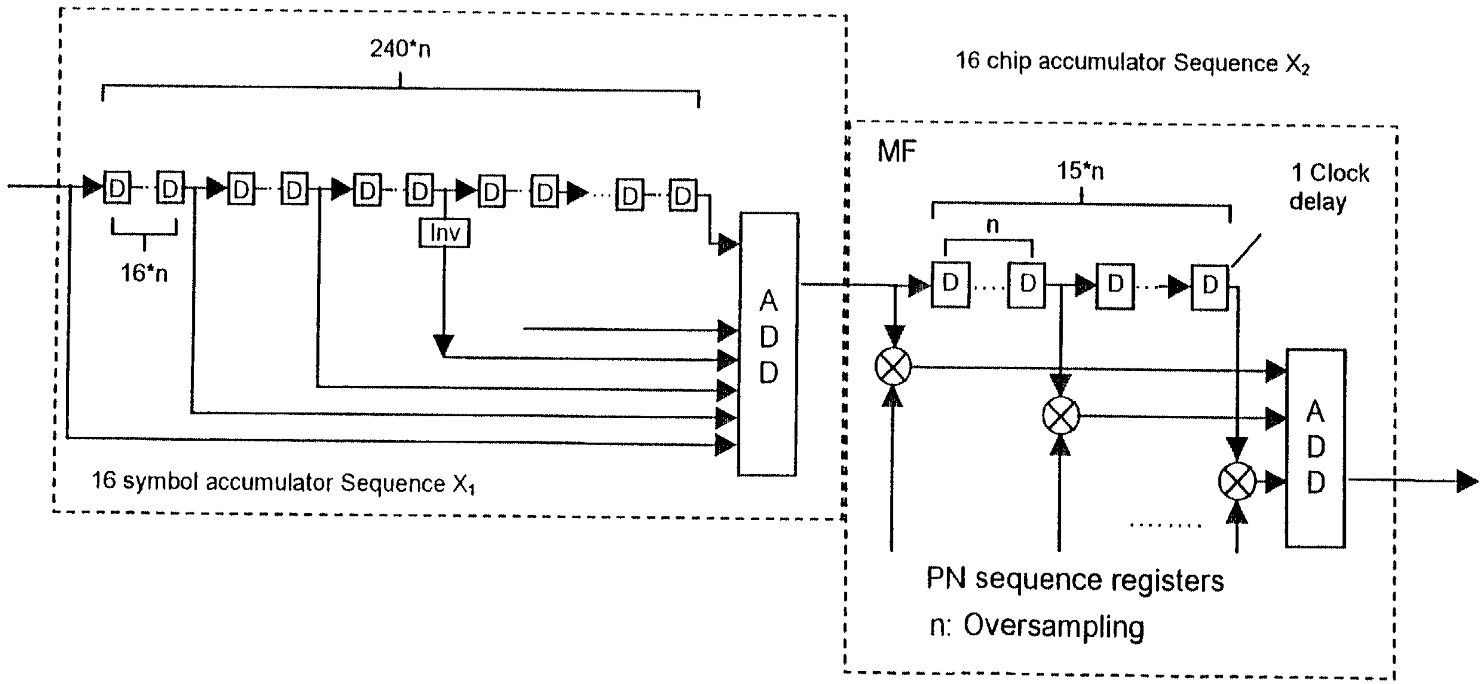


Fig 6

10/018436

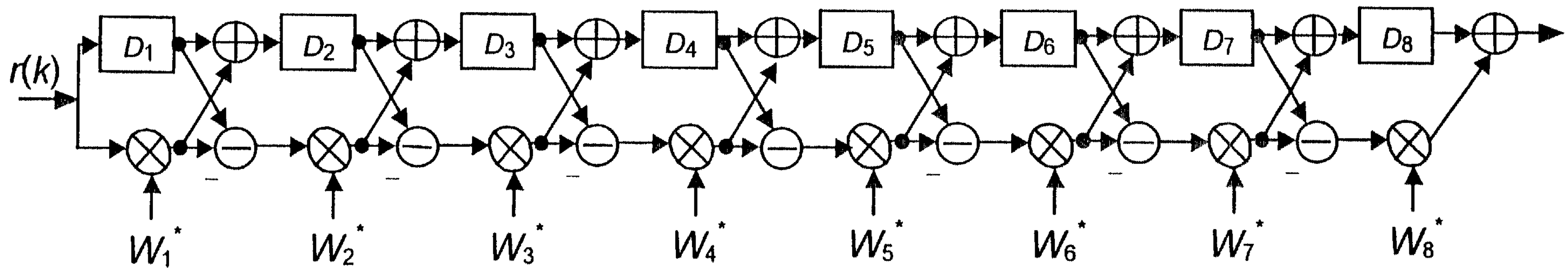


Fig 7

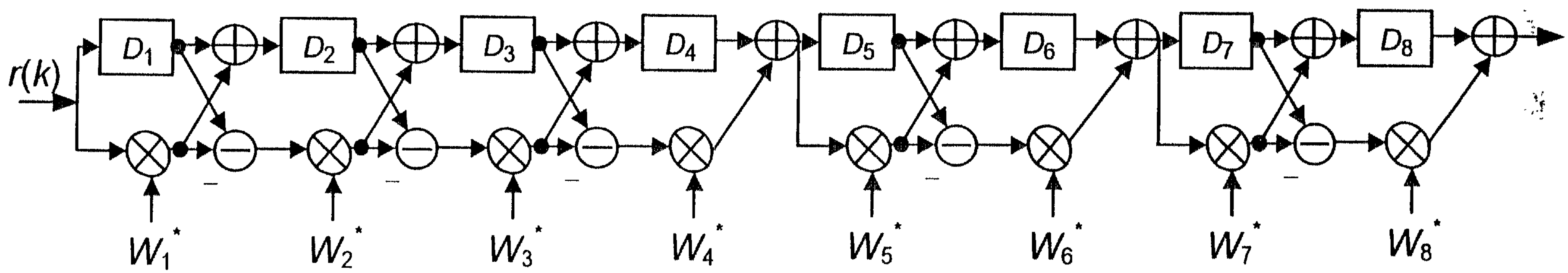


Fig 8

10/018436

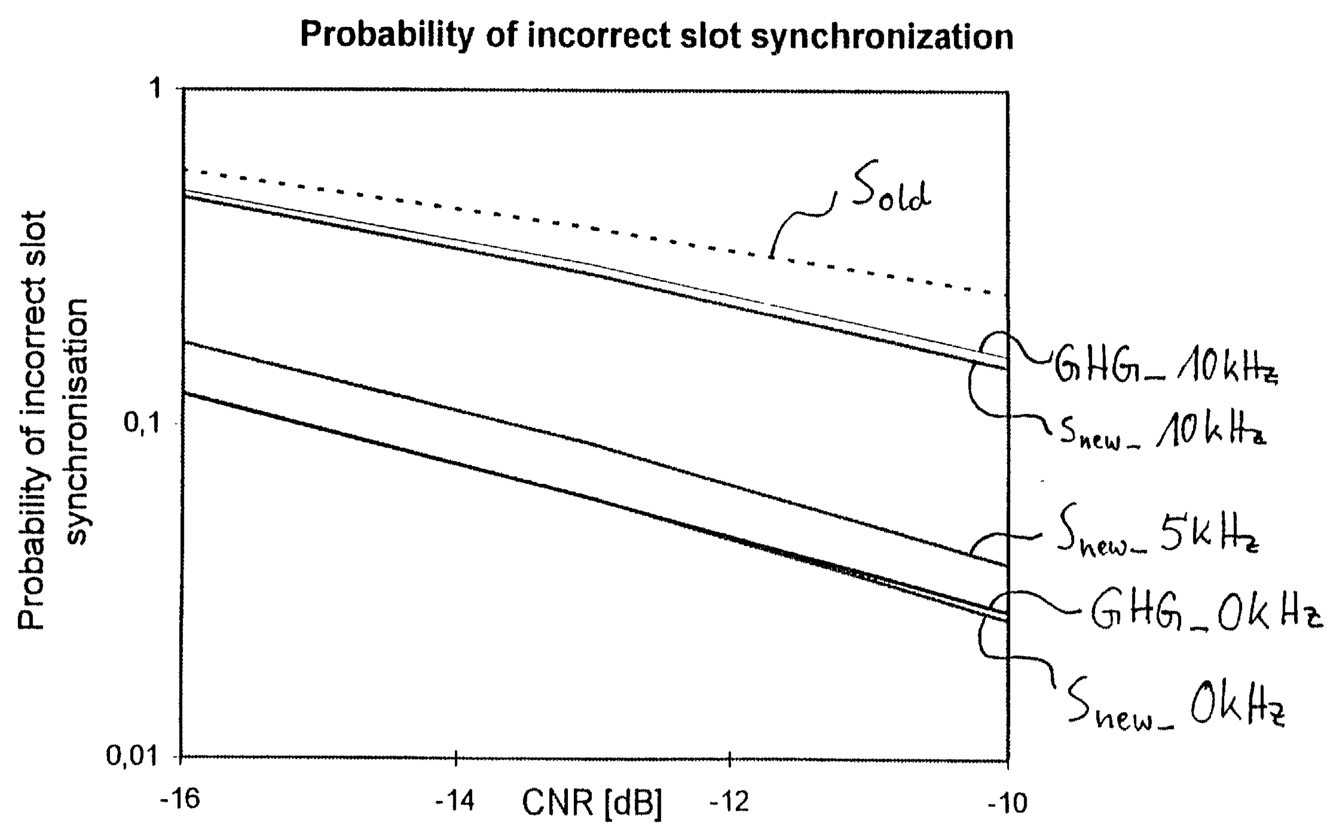


Fig 9

Declaration and Power of Attorney For Patent Application
Erklärung Für Patentanmeldungen Mit Vollmacht
German Language Declaration

Als nachstehend benannter Erfinder erkläre ich hiermit an Eides Statt:

dass mein Wohnsitz, meine Postanschrift, und meine Staatsangehörigkeit den im Nachstehenden nach meinem Namen aufgeführten Angaben entsprechen,

dass ich, nach bestem Wissen der ursprüngliche, erste und alleinige Erfinder (falls nachstehend nur ein Name angegeben ist) oder ein ursprünglicher, erster und Miterfinder (falls nachstehend mehrere Namen aufgeführt sind) des Gegenstandes bin, für den dieser Antrag gestellt wird und für den ein Patent beantragt wird für die Erfindung mit dem Titel:

Verfahren zur Bildung bzw. Ermittlung einer Synchronisationsfolge, Verfahren zur Synchronisation, Sendeeinheit und Empfangseinheit

deren Beschreibung

(zutreffendes ankreuzen)
☐ hier beigefügt ist.
☒ am 16.02.2000 als
PCT internationale Anmeldung
PCT Anmeldungsnummer PCT/EP00/01263
eingereicht wurde und am ______
abgeändert wurde (falls tatsächlich abgeändert).

Ich bestätige hiermit, dass ich den Inhalt der obigen Patentanmeldung einschliesslich der Ansprüche durchgesehen und verstanden habe, die eventuell durch einen Zusatzantrag wie oben erwähnt abgeändert wurde.

Ich erkenne meine Pflicht zur Offenbarung irgendwelcher Informationen, die für die Prüfung der vorliegenden Anmeldung in Einklang mit Absatz 37, Bundesgesetzbuch, Paragraph 1.56(a) von Wichtigkeit sind, an.

Ich beanspruche hiermit ausländische Prioritätsvorteile gemäss Abschnitt 35 der Zivilprozessordnung der Vereinigten Staaten, Paragraph 119 aller unten angegebenen Auslandsanmeldungen für ein Patent oder eine Erfindersurkunde, und habe auch alle Auslandsanmeldungen für ein Patent oder eine Erfindersurkunde nachstehend gekennzeichnet, die ein Anmeldedatum haben, das vor dem Anmeldedatum der Anmeldung liegt, für die Priorität beansprucht wird.

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

Method of generating and/or detecting synchronization sequences, synchronization method, transmitter unit and receiver unit

the specification of which

(check one)
☐ is attached hereto.
☒ was filed on 16.02.2000 as
PCT international application
PCT Application No. PCT/EP00/01263
and was amended on ______
(if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

IDNR: 2590 / V: 99-1.00 / B:Val

Form PTO-FB-240 (8-83)

Patent and Trademark Office-U.S. DEPARTMENT OF COMMERCE

German Language Declaration

Prior foreign appplications
Priorität beansprucht

Priority Claimed

19919545.5	DE	29.04.1999	☒ Yes / Ja	☐ No / Nein
(Number) (Nummer)	(Country) (Land)	(Day Month Year Filed) (Tag Monat Jahr eingereicht)		
99109791.6	EP EP	18.05.1999	☒ Yes / Ja	☐ No / Nein
(Number) (Nummer)	(Country) (Land)	(Day Month Year Filed) (Tag Monat Jahr eingereicht)		
			☐ Yes / Ja	☐ No / Nein
(Number) (Nummer)	(Country) (Land)	(Day Month Year Filed) (Tag Monat Jahr eingereicht)		

Ich beanspruche hiermit gemäss Absatz 35 der Zivilprozessordnung der Vereinigten Staaten, Paragraph 120, den Vorzug aller unten aufgeführten Anmeldungen und falls der Gegenstand aus jedem Anspruch dieser Anmeldung nicht in einer früheren amerikanischen Patentanmeldung laut dem ersten Paragraphen des Absatzes 35 der Zivilprozeßordnung der Vereinigten Staaten, Paragraph 122 offenbart ist, erkenne ich gemäss Absatz 37, Bundesgesetzbuch, Paragraph 1.56(a) meine Pflicht zur Offenbarung von Informationen an, die zwischen dem Anmeldedatum der früheren Anmeldung und dem nationalen oder PCT internationalen Anmeldedatum dieser Anmeldung bekannt geworden sind.

I hereby claim the benefit under Title 35. United States Code. §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §122, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occured between the filing date of the prior application and the national or PCT international filing date of this application.

PCT/EP00/01263	16.02.2000	anhängig	pending
(Application Serial No.) (Anmeldeseriennummer)	(Filing Date D, M, Y) (Anmeldedatum T, M, J)	(Status) (patentiert, anhängig, aufgegeben)	(Status) (patented, pending, abandoned)
(Application Serial No.) (Anmeldeseriennummer)	(Filing Date D,M,Y) (Anmeldedatum T, M; J)	(Status) (patentiert, anhängig, aufgeben)	(Status) (patented, pending, abandoned)

Ich erkläre hiermit, dass alle von mir in der vorliegenden Erklärung gemachten Angaben nach meinem besten Wissen und Gewissen der vollen Wahrheit entsprechen, und dass ich diese eidesstattliche Erklärung in Kenntnis dessen abgebe, dass wissentlich und vorsätzlich falsche Angaben gemäss Paragraph 1001, Absatz 18 der Zivilprozessordnung der Vereinigten Staaten von Amerika mit Geldstrafe belegt und/oder Gefängnis bestraft werden koennen, und dass derartig wissentlich und vorsätzlich falsche Angaben die Gültigkeit der vorliegenden Patentanmeldung oder eines darauf erteilten Patentes gefährden können.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

German Language Declaration

VERTRETUNGSVOLLMACHT: Als benannter Erfinder beauftrage ich hiermit den nachstehend benannten Patentanwalt (oder die nachstehend benannten Patentanwälte) und/oder Patent-Agenten mit der Verfolgung der vorliegenden Patentanmeldung sowie mit der Abwicklung aller damit verbundenen Geschäfte vor dem Patent- und Warenzeichenamt: *(Name und Registrationsnummer anführen)*

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. *(list name and registration number)*

29177 And hereby appoint
PATENT & TRADEMARK OFFICE

Customer No. 29177

Telefongespräche bitte richten an: *(Name und Telefonnummer)*

Direct Telephone Calls to: *(name and telephone number)*

Ext. ____________

Postanschrift:

Send Correspondence to:

Bell, Boyd & Lloyd LLC
Three First National Plaza, 70 West Madison Street, Suite 3300 60602-4207 Chicago, Illinois
Telephone: (001) 312 372 11 21 and Facsimile (001) 312 372 20 98
or
Customer No. 29177

1-00

Voller Name des einzigen oder ursprünglichen Erfinders: Dr. JUERGEN MICHEL	Full name of sole or first inventor: Dr. JUERGEN MICHEL
Unterschrift des Erfinders: X Jürgen Michel — Datum: 5.10.01	Inventor's signature — Date
Wohnsitz: MUENCHEN, DEUTSCHLAND	Residence: MUENCHEN, GERMANY DEX
Staatsangehörigkeit: DE	Citizenship: DE
Postanschrift: SEBASTIAN-BAUER-STR.35	Post Office Addess: SEBASTIAN-BAUER-STR.35
81737 MUENCHEN	81737 MUENCHEN

2-00

Voller Name des zweiten Miterfinders (falls zutreffend): BERNHARD RAAF	Full name of second joint inventor, if any: BERNHARD RAAF
Unterschrift des Erfinders: X Bernhard Raaf — Datum: 8.10.01	Second Inventor's signature — Date
Wohnsitz: MUENCHEN, DEUTSCHLAND	Residence: MUENCHEN, GERMANY DEX
Staatsangehörigkeit: DE	Citizenship: DE
Postanschrift: MAXHOFSTR. 62	Post Office Address: MAXHOFSTR. 62
81475 MUENCHEN	81475 MUENCHEN

(Bitte entsprechende Informationen und Unterschriften im Falle von dritten und weiteren Miterfindern angeben).

(Supply similar information and signature for third and subsequent joint inventors).